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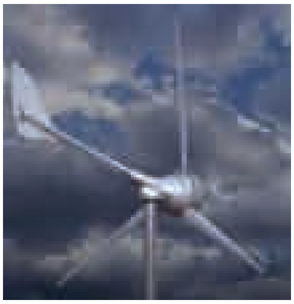

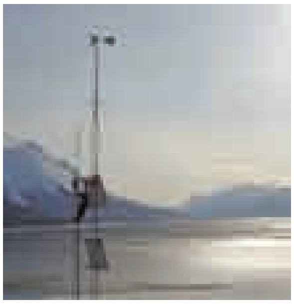

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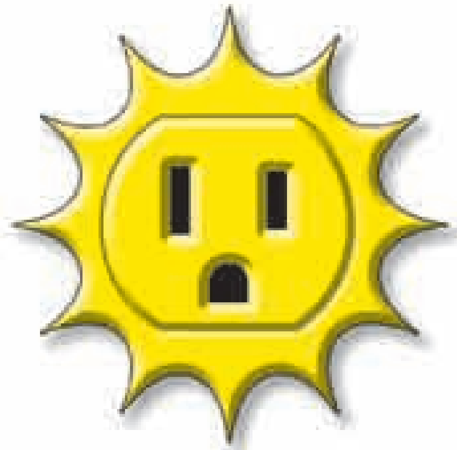


contents

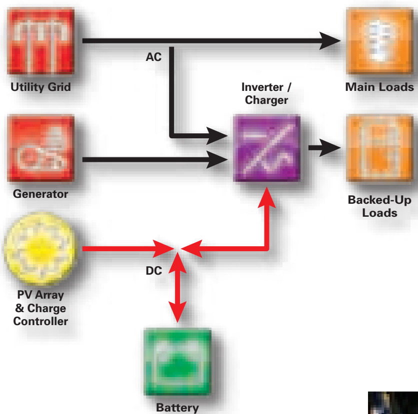
June & July 2010

Photos (clockwise from bottom left): www.quickmountpv.com, Chuck Marken, www.tigoenergy.com, www.endurancewindpower.com, Lael Eccard, Michael Lamb

On the Cover

Derek Sabin of Sustainable Energy Developments performs routine maintenance on a Bergey Excel turbine atop a 120-foot tower in Munnsville, New York.

Photo by Bill Court



Regulars

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from us *to you*

PROMISING WINDS

It's often said that wind electricity is cheaper than solar electricity. While this is clearly true on the utility scale, the conclusion is less often justified on the home scale. Why?

Part of it is the understanding of the resource. Most people grasp the necessity for placing solar-electric modules in the sun—we have tools to analyze shading and can calculate solar availability. But estimating a wind resource is trickier, and there's a widespread lack of knowledge about what a good wind resource is—and what is required to use it. Simple answer: We need tall towers to get into viable wind resources. On a tower that's too short, the best turbine will always underperform, wasting your RE investment.

The other major reason that home-scale wind systems are often less economical than solar electricity is *reliability.* If you compare the two technologies side by side and mistakenly assume that both will be reliable, wind often comes out on top. But in the real world, solar-electric systems are *very* reliable, and wind-electric systems simply are not. In my 26 years of working with small wind-electric systems, I can't point at *even one* system and say, "That's been trouble-free for a decade without attention." All wind-electric systems need regular maintenance, and most home-scale wind-electric systems need multiple repairs in their lifetime. This all costs money, which increases the cost of energy for these systems.

A few things coming down the small wind pike may help improve the situation:

- The American Wind Energy Association (AWEA) passed a small wind standard in December 2009, which gives manufacturers quality targets that are quantifiable.
- The Small Wind Certification Council (SWCC) is up and running, and taking applications for certifying turbines to the AWEA standard (see *News & Notes*, this issue).
- Small wind systems will have a section in the next edition of the *National Electrical Code (NEC)*, which may lead to safer and more reliable systems.
- The first small wind installer exam will be offered in September by the North American Board of Certified Energy Practitioners (NABCEP), which may lead to higher-quality installations.
- In June, the sixth annual Small Wind Conference in Stevens Point, Wisconsin, will focus on no-nonsense interchange between wind installers, manufacturers, and other wind professionals, educating the industry toward realistic expectations.
- Manufacturers are ratcheting up their commitment to quality. For example, Bergey Windpower is now offering a 10-year warranty on its Excel turbine.

Efficiency, performance claims, design improvements, and cool new configurations are all worthless for small wind if we don't have *reliability.* This is the number-one criteria for judging a wind generator, since without it, other qualities will make no difference. Check out our buyer's guide on page 44 for the straight scoop on established and supported machines available in North America.

—Ian Woofenden for the *Home Power* crew

Think About It...

The pessimist complains about the wind;
the optimist expects to change it; the realist adjusts the sails.

—William Arthur Ward

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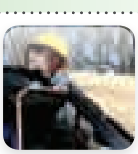

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POWERING YOUR FUTURE

Apples to Apples

Small Wind Certification Labels Expected in Late 2010

Buyers of small wind turbines for homes, farms, or small businesses are faced with choosing from more than 450 products from nearly 200 suppliers. Very few have been tested or independently evaluated, leaving early customers to serve as beta or prototype testers. The result has been that safety concerns and disappointed customers have slowed the expansion of the small wind industry.

To protect consumers from poor products and help small wind technology gain mainstream acceptance, the Small Wind Certification Council (SWCC; www.smallwindcertification.org) recently launched an effort to independently test and certify the numerous "commercially available" small wind turbines (up to 200 square meters swept area or about 65 kW). The group will certify that small wind turbines meet or exceed the requirements of the new American Wind Energy Association's *Small Wind Turbine Performance and Safety Standard*, a new North American standard for testing and evaluating turbine designs, and reporting turbine energy and sound performance. A certified turbine will carry the SWCC's third-party label, confirming that it has been tested and allowing consumers easier comparison shopping.

Certification can help prevent unethical marketing and false claims, ensuring consumer protection and industry credibility. Widespread adoption of certification labels will also allow funding agencies and utilities to gain greater confidence that small wind turbines are safe and will perform as expected—which is especially important with publicly funded projects.

The SWCC's certification launch coincides with a dramatic increase in small wind turbine testing activities across North America, and is a direct response to funding agencies and utilities pushing for an independent certification program. Renewable energy incentive programs in Massachusetts, New York, and Wisconsin were the first to require SWCC or similar certification for incentive eligibility. The Energy Trust of Oregon will use the SWCC certification as the preferred method for qualifying wind turbines and estimating annual energy output. Numerous programs in other states also are considering such requirements.

In February, the SWCC began accepting Notices of Intent (NOI) to submit applications from small wind turbine manufacturers, designers, and authorized designees—the first step in pursuing SWCC certification. Applicants provide basic information about the turbine(s),

a description of testing and evaluation plans, as well as design drawings, operation manuals, photos, and other details. Applicants are advised to submit their NOIs before beginning testing to be sure that test plans conform to SWCC requirements.

Poised to help increase demand for wind turbines, the SWCC is seeking to populate a list of independently certified small wind turbines for the North American market. The SWCC expects to announce its first batch of certified turbines later this year.

—Heather Rhoads-Weaver

The Other Wind Certification

The North American Board of Certified Energy Practitioners (NABCEP) is a highly respected program for testing and certification of individual installers of RE systems. So far, NABCEP has certifications for PV and solar thermal installers, but is also completing a task analysis for wind installers—the first step for the new certification for wind system pros.

Federal Bulb Ban

In the dark about the government's plans to pull the plug on the 125-year-old incandescent light bulb? If so, then you're not alone.

According to a recent survey by GE Lighting, most Americans are not aware that incandescent light bulbs will no longer be sold in the United States as of 2014. In accordance with provisions in the 2007 Energy Independence and Security Act, the incandescent phase-out will begin with the 100 W bulb in 2012 and end in 2014 with the 40 W.

The phase-out marks the official start of the country's changeover to more energy-efficient lighting, such as compact fluorescent (CF) and light-emitting diode (LED) lamps. The legislation also mandates that all light bulbs sold in the United States must use 25% to 30% less energy than 2007 incandescent bulbs by 2014, and be 70% more efficient by 2020.

The survey showed that 82% of Americans said they are aware of the energy-saving benefits of CF bulbs and already use them at home. Yet, 80% also said they use incandescent bulbs as well.

While it may be lights-out for the incandescent bulb, the future still looks bright. The American Council for an Energy Efficient Economy estimates that the new standards will save consumers $40 billion in energy and other costs from 2012 to 2030; avoid construction of the equivalent of 14 coal-fired power plants; and cut global-warming emissions by at least 51 million tons of carbon dioxide annually.

—Kelly Davidson

Data Logging & System Monitoring

Courtesy www.aprsworld.com

APRS World's (www.aprsworld.com) **Wind Data Logger #40R** package ($855) is a complete solar-powered wind data logger for site or turbine performance. Powered by a 10 W PV module, the data logger records wind speed, gust, and direction, along with time and date, temperature, and other useful wind parameters. It can record wind speed for up to three anemometers, which is helpful for more complex wind analysis. The package includes an anemometer, 100 feet of cable, a waterproof housing, the PV module, a 7 Ah sealed AGM battery, and a solar charge controller.

Also just being released from APRS World is its **Tap** line of RE system and equipment monitoring products ($200 to $400). Available for many RE products including those from OutBack Power, Magnum Energy, Morningstar, and Bergey Windpower, Taps pass collected data (via their gateway module and an Internet router) to APRS World's Web site, enabling users to monitor their RE equipment from any Internet-connected computer.

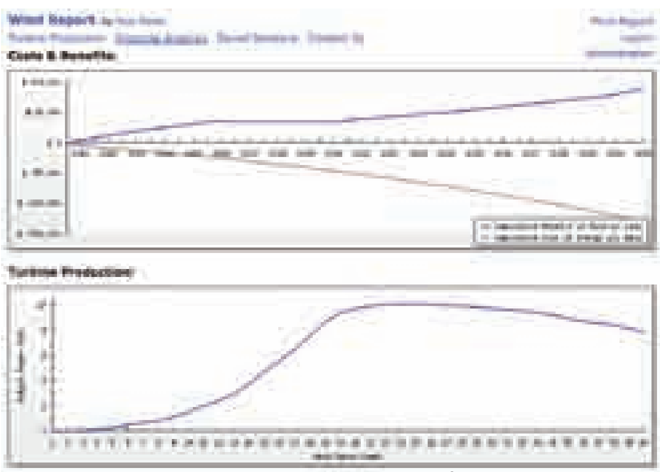
Online data monitoring is common for grid-tied systems, and now the APRS World Tap makes it easier for off-grid data to be accessed online. Installers and system owners can easily keep tabs on system performance and even troubleshoot systems remotely.

The APRS World data Web page for each customer can be customized to provide live system data and daily graphs for many system parameters, such as from the battery bank (state of charge, charging or discharging watts, Ah in or out, and voltage) and inverter (status, inverting and/or charging mode, and electronics temperatures). Taps sensors can also be used for other things, like collecting weather data from anemometers and temperature. Data hosting by APRS World is included in the product cost, but customized data Web pages and services may cost extra.

Financial Modeling Software

New Roots Energy (www.newrootsenergy.com) has released its **Wind Report** ($99 for three-month subscription), an online program that crunches numbers to help determine the financial viability of wind systems. Users input wind system parameters such as wind generator make and model, average wind speed, and tower height, along with financial parameters such as estimated system cost, annual energy consumption, utility electricity rate, and loan interest rate and payback period. Available state and federal wind power incentives are automatically incorporated in the financial analysis. Once all of the parameters are entered, the system predicts monthly and annual kWh production, generates a cost/benefit graph, and estimates return on investment. The financial metrics used are lifetime cost of energy, internal rate of return, net present value, and payback. Cash-flow tables are provided and take into account depreciation, taxes, and energy savings. For systems that are financed, the program calculates tax savings on interest payments. Users can use this software to quickly compare various wind generator and financing options before purchasing equipment.

—Justine Sanchez



Courtesy www.newrootsenergy.com

the Lumina Project

Empowering manufacturers with research and data to make smart off-grid lighting solutions for developing countries

In 1995, after attending a meeting in India of the International Commission on Illumination, Evan Mills decided to take a side trip to Varanasi, the oldest known city in the world. While walking along a narrow street one night, he saw a man crouched down, selling a spread of beads and bangles by the glow of a kerosene lantern.

Mills, then a staff scientist at Lawrence Berkeley National Laboratory researching energy efficiency, couldn't help wondering how many people were lighting by flame in their homes or workplaces. How much fuel did they use each year? And how did the low quality and high cost of this lighting impact their lives?

"That moment really clinched it," he says. "The human dimension of this problem became clear, as did the huge potential for improving people's lives—not to mention saving enormous amounts of energy—with better alternatives."

Traditional kerosene-fueled hurricane lantern (left) and a prototype LED lantern (right) in Sauri, Kenya.

Courtesy Evan Mills

Working on his own, mostly at night and on weekends, Mills began studying off-grid lighting methods used in several countries—and exploring how white LED light sources could help reduce the dependency on flame-based lighting. This culminated in the first published estimate of global expenditures and energy use on fuel-based lighting: $40 billion per year and greenhouse-gas emissions equaling those from 30 million cars.

Inspired by the fundamental linkages between light—or the lack thereof—and literacy, commerce, safety, health, and general development, Mills hatched a plan to develop low-cost, miniaturized LED lighting systems that could be powered with small PV modules and inexpensive rechargeable AA batteries.

Mills began measuring fuel-use rates and light output from kerosene lanterns, and comparing those results to off-the-shelf LED products such as headlamps. He was later invited to help teach a class at Stanford University, where undergraduate and graduate students in design, engineering, and business came together to craft LED prototypes and business plans for test markets in China, Mexico, and India. This process helped Mills develop an appreciation for user-centered design and the imperative for affordability. Students from UC Berkeley later sought his help in conducting more in-depth field research in India, Tibet, and Africa.

Arne Jacobson, professor and co-director of the Schatz Energy Research Center at Humboldt State University in Arcata, California, became a close collaborator, working with Mills to establish a testing lab and develop a performance and quality testing protocol for products that were coming to market. They found problems with virtually every component, from the LEDs themselves to the PV modules and the batteries.

The work gained momentum in 2006 when the project received seed funding from the Blum Center for Developing Economies. Taking an analytical approach to promoting clean energy alternatives, the nonprofit Lumina Project, as it became known, continues to conduct field projects and laboratory testing to compile information aimed at helping manufacturers improve the viability of LED-based lighting products for the developing world.

"The biggest barrier is the market-spoiling effect that happens when low-quality products are dumped into these markets," Mills says. "They can dissuade a whole generation of people from trusting the underlying, good technology."

One of the Lumina Project's key goals, Mills says, is to help manufacturers develop quality products that are affordable for the masses and do not require subsidies or charity models to deploy.

The project has involved about 20 researchers and students to date, and is currently completing market tests in Kenya, where LED systems have been sold to small businesses, night guards, and homeowners through existing market channels at true market prices. The study is collecting data on affordable price points, total cost of ownership, user satisfaction, usage patterns, and durability. This data, says Mills, is relayed to manufacturers, investors, and policymakers, which helps them understand market expectations as well as the realities of what product characteristics are desired and what is affordable.

The real highlight of Lumina's work so far, says Mills, is how the World Bank and the International Finance Corporation leveraged the project to develop their Lighting Africa initiative, which conducts widespread market research, product testing, and market development across sub-Saharan Africa. At the Copenhagen Climate Summit last December, U.S. Secretary of Energy Steven Chu launched an even larger initiative—the Solar and LED Energy Access Program (SLED).

Other Illuminating Projects

- Working with the United Nations to qualify clean-energy off-grid lighting projects for carbon credits
- Equipping LED systems in Kenya with instruments to measure how much of the available solar resource the users actually capture, and whether the PV modules are properly sized in existing products
- Helping avoid brownouts in renewable micro-grids by evaluating how LEDs might work with other "smart-grid" strategies to provide lighting that can deal with voltage spikes, while reducing overall demand
- Identifying and measuring indoor air pollutants emitted by kerosene lanterns

"When we talk to people in Africa who have bought the lights and they say, for example, that they can keep their shops open longer or do more business with the better light, we know we're on the right track," Mills says.

—Kelly Davidson


Courtesy Habitat for Humanity

Habitat for Humanity's New PV System

Sun's Eye Power teamed up with the nonprofit organizations Habitat for Humanity and the Northwest Solar Group to install a 2.2 kW grid-tied PV system on a new home in Tacoma, Washington. Sun's Eye Power provided the system design and conducted training for volunteer installers recruited by the Northwest Solar Group. Habitat solicited donations to purchase the equipment. And the Gabriel family—two adults and four children—were the fortunate recipients of the solar house.

Habitat's goal was to provide an energy-efficient home with low electricity bills for the new homeowners. The home is conventionally constructed with a 2 x 6 frame, but is wrapped with 2 inches of rigid foam to provide additional insulation and reduce air infiltration. All of the appliances are Energy Star-rated, and fluorescent lighting is used throughout.

Habitat wanted to offset 30% of the home's estimated 6,000 kWh annual electrical needs with solar. In Tacoma, with an average 3.7 daily sun-hours, a 2.2 kW PV system meets this goal. Sun's Eye Power specified microinverters for this system, where each module would be matched with its own inverter.

The installation was straightforward: first, standoffs; second, rails; third, inverters; fourth, modules; and finally, connection to the electrical service. Because microinverters were used, no additional DC wiring was necessary. The installation was plug-and-play, which was terrific since volunteers with limited electrical experience helped install the system. The wide channels in the SnapNrack rails hide module and inverter cables, making a very clean-looking installation.

The enthusiastic volunteers had the system up and running in less than six hours, and the system went online on October 1, 2009. By mid-March of this year, it had generated 793 kWh.

—Brad Burkhartzmeyer

OVERVIEW

Project name: Habitat for Humanity at Larabee Terrace, Tacoma, Washington

System type: 2.2 kW grid-tied PV

Installer: Brad Burkhartzmeyer, Sun's Eye Power Company

Date commissioned: October 2009

Location: Tacoma, Washington, 47°N latitude

Solar resource: 3.7 average daily sun-hours

Array capacity: 2.2 kW STC

Average annual production: 2,100 kWh

Average annual utility electricity offset: 30%

EQUIPMENT SPECIFICATIONS

Modules: 10 REC Solar REC220AE-US, 220 STC W each

Inverter: 10 Enphase M190-72-240-S12

Array installation: Roof-mounted with SnapNrack rail on asphalt shingle roof using standoff brackets installed prior to new roof. Azimuth is true south; tilt is 18°

Battery-to-Inverter Circuit Breaker AIC & Sizing

The circuit breaker between the battery bank and an inverter's DC connections must be rated for DC use and have a high amps interrupting capacity (AIC). The breaker's AIC is an indication of its ability to safely maintain an open circuit during a catastrophic short-circuit condition. Too low of an AIC could result in internal damage that could allow the breaker to continue conducting.

The *National Electrical Code* 690.71(C) requires a fuse in series with a low-AIC circuit breaker. For most residential systems, a 50 kA AIC is sufficient, as current is limited by the combination of the battery bank's internal resistance and the battery cabling resistance. But AC breakers, even those few rated for DC applications, usually aren't satisfactory. For example, the Square D QO series circuit breaker is an AC breaker popular with branch circuit applications. Its AC AIC is 10 kA, but its UL-listed 48 VDC AIC is just 5 kA.

DC Rated Circuit Breaker with High AIC

The breaker should be sized in accordance with *NEC* 690.8(A)(4) "Stand Alone Inverter Input Circuit Current." Key variables include the inverter's rated power, lowest input voltage, and full-power efficiency. For example, the appropriate DC circuit breaker for use with an inverter rated at 2,500 VA, a minimum operating battery voltage of 22 VDC, and that has an 85% efficiency rating would require a 175 A DC circuit breaker:

The rated (full) power efficiency (i.e., 85%) and the minimum DC operating voltage (i.e., 22 VDC) specs are usually provided in the detailed inverter specifications.

2,500 VA ÷ 22 VDC = 113.6 A DC
113.6 A ÷ 0.85 = 133.7 A
133.7 A x 1.25 (*NEC* continuous duty safety factor) = 167.1 A
Round up to the next standard size (per *NEC* 240.4(B)) = 175 A

DC-rated circuit breakers are designed to manage make-or-break contact arcs that are considerably worse that those seen in AC applications, where the alternating current tends to "self-extinguish" the arc when the sine wave hits 0 V. In fact, many DC-rated circuit breakers are now polarized, with line and load designations for the terminals; the battery bank—generally the highest current source—should be connected to the line terminal. As a result, DC breakers are relatively large and rugged, and they are often rated for 100% continuous duty for their specified conditions of use (i.e., ambient temperature). *NEC* 690.8(B)(1)(EX) makes an exception to the 125% safety factor for circuits and breakers that are listed for 100% continuous-duty operation.

For example, the sizing for a 100% continuous-duty rated DC breaker for a 24 VDC, 4,000 VA inverter would be:

4,000 VA rated power ÷ 22 VDC minimum = 181.82 A DC
181.82 A ÷ 85% inverter efficiency = 214 A
Round up to the next standard size = 250 A

—James Goodnight

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Not just another golf car battery with a fancy new "RE" label. U.S.Battery has made real improvements from the inside out.

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The primary causes of positive plate deterioration are positive grid corrosion and positive active material wear-out or softening and shedding. These failure modes are the result of the normal overcharge required to fully charge batteries and to mix the electrolyte to prevent electrolyte stratification. In addition, batteries that are used in applications that require continuous float charging may be more susceptible to grid corrosion as a result of prolonged overcharging. Also, batteries that are subjected to frequent deep discharges (greater than 50% DOD) often exhibit increased effects from positive active material wear-out. This is usually the case in Renewable Energy applications. Testing at U.S.Battery has shown that an effective method for mitigating the effects of positive plate deterioration is to increase the ratio of positive to negative active material by ***adding a positive plate*** and removing a negative plate from a conventional cell design resulting in an Outside Positive (OSP™) cell design vs a conventional Outside Negative (OSN) cell design. This design approach results in a cell with increased positive to negative active material ratio, increased positive to negative grid ratio, and increased protection of the positive plate from positive plate deterioration. This results in longer life, increased capacity, and more stable performance over the life of the battery.

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Electrical shorting can be caused by 'mossing' shorts at the top of the cell element. These mossing shorts are the result of positive active material particles that have softened and shed from the positive plates, become suspended in the electrolyte, and eventually collect at the top of the cell element. Once enough of this material has collected to bridge the tops of the separators, it can contact both a positive and a negative plate where it converts to conductive lead and forms a short circuit resulting in cell and battery failure. This failure mode is more prevalent in stationary applications than in vehicular applications because of the absence of vibration and shock that normally dislodges the mossing material and causes it to fall to the bottom of the container where it collects innocuously in the mud cells. Testing at US Battery has shown that the use of insulating 'moss shields' in batteries used in these stationary applications can effectively prevent the formation of these mossing shorts. This results in longer life, increased capacity, and more stable performance over the life of the battery.

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AMP HOURS (20hr.rate)	428
AMP HOURS (5hr.rate)	334
MINUTES (@ 75 AMPS)	254
MINUTES (@ 25 AMPS)	914
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Courtesy Guy Marsden

A Central Maine Power employee replaces Guy Marsden's meter.

Subsidy Reality

In Guy Marsden's "Microinverters Make a Simple Installation," (*HP136*), he says, "I showed that a payment from CMP [Central Maine Power] of 50 cents per kWh would significantly incentivize small-scale residential solar generators."

I am sure a subsidy of five times the going rate would incentivize just about anything. A $10 a gallon subsidy should do wonders for gasoline consumption. Come on, Guy—get real! Subsidies on that scale would bankrupt all of the utilities in the United States. It ain't going to happen, nor should it.

Chris Green • via e-mail

There are many misconceptions concerning the so-called "feed-in tariff" concept. If you want to see a good overview of how it works and why it has been so successful in Europe, I suggest you read the Wikipedia page: www.en.wikipedia.org/wiki/Feed-in_tariff.

Note, for instance, that Ontario, Canada's rates are at 82 cents (Canadian) per kWh. Vermont currently pays 30 cents. Each legislative group puts a different spin on the basic implementation with varying degrees of success. Higher payouts work as better incentives. But it is always the ratepayers who contribute to the funding, not the utility.

Our Maine legislators were reluctant to "tax" the ratepayers, despite the fact that the cost would be so trivial as to go unnoticed on most monthly bills. Our group pitched the cost as "a pizza per year" for residential ratepayers. The Utility Committee also explored exemptions for big industry. Ultimately, the bill failed due to many misconceptions by the committee members, despite a lot of lobbying and education from our group, the Midcoast Green Collaborative.

Guy Marsden • Woolwich, Maine

How Smart?

Smart meters are rolling across the United States and Canada, and their virtues are sung far and wide by the power providers. Superficially, the arguments that the power providers are promoting seem realistic. Scratch the surface and ugly truths emerge.

Smart grids and smart meters are smart for the electricity providers, but may end up costing consumers more money. The grid should have been continuously upgraded over the last six decades (normal capital improvements from utilities' generous profits). The U.S. government has approved an increase in billing charges to cover what should have been normal business practices of improving or "smartening" the grid. In Ontario, Canada, our backward government is negotiating for more nuclear reactors. Our citizens have a $36 billion retired or stranded debt, of which $22 billion is from nuclear power plants. Our grid is being upgraded to handle the increased energy consumption and production (the latter is blamed on the wind turbine industry).

Smart meters have the ability to give users exact information on the amount of electricity being used at any point in time. They show the consumer what their consumption rate is, but not what appliance is using energy, what is using the most energy, or what energy is being wasted. A watt/kWh meter like the Kill A Watt is a simple and easy-to-use item, enabling consumers to make these determinations.

Load shedding via smart meters! What a great idea! Imagine the utilities assuming the responsibility on behalf of consumers for deciding who gets how much electricity for what appliances and when (without regard to the effect on your appliances). How kind! Will they do this for office buildings, factories, and shopping malls, or will businesses be allowed to use electricity at optimum levels?

Smart meters have the ability to be set up for prepayment—a direct attack on seniors and people on fixed incomes. It is hard to budget electrical use because of variable conditions like the weather. Fixed incomes do not allow most families to purchase the latest energy-efficient appliances, HVAC equipment, or even compact fluorescents. Making trips to the corner store to top up your electricity card at the end of the month may not be financially or physically possible, or convenient.

Canadians and Americans are huge consumers of electricity—some even say we are energy hogs. Realistically, we all must decrease our wasteful consumption

(continued on page 34)

of electricity. We also must use other resources in a much less wasteful way. People must take responsibility for their wasteful habits, and this is now happening because of awareness and the hammer of higher costs. Industry, offices, and commercial establishments must start taking responsibility to reduce their demand on resources. Manufacturers must supply the consumers with more energy-efficient goods at a reasonable cost. Governments must take action to ensure that all of this happens by enacting standards for energy efficiency.

Smart meters put the onus on individuals who have the least power to make a difference, and the difference that they make is small in comparison to what could or should be attained. The time is here for *all* concerned to take responsibility for using our resources in a sustainable manner. Smart meters fall far short of this goal.

Ron Challis • Newbury, Ontario, Canada

Calculating CO_2

Adding to the carbon dioxide (CO_2) correction letter in the *HP136 Circuit Mail,* here's something that your readers may find informative and useful. You can calculate the amount of CO_2 produced per kilowatt-hour (kWh) generated using specific fuels and specific types of generators with the following: Divide the CO_2 emissions factor for the fuel (in pounds of CO_2 per million Btu) by the heat rate of the generator—the amount of heat (in Btu) used to generate 1 kWh.

For example, the table (above) has the calculated number of pounds of CO_2 produced by a steam-electric generator for different fuels. The CO_2 emissions factors for fuels burned at power plants can be found on the U.S. Energy Information Administration's Web site at: www.eia.doe.gov/cneaf/electricity/epa/epata3.html. The average annual heat rates of U.S. electric power generators can be found at: www.eia.doe.gov/cneaf/electricity/epa/epat5p4.html.

CO_2 Content of Electrical Energy from Various Fuels

Fuel	Lbs. of CO_2 per Million Btu	=	Lbs. of CO_2 per Btu	×	Heat Rate* (Btu per kWh)	=	Lbs. of CO_2 per kWh
Lignite coal	215.400		0.000215400		10,138		2.18
Waste oil	210.000		0.000210000		10,360		2.18
Sub-bituminous coal	212.700		0.000212700		10,138		2.16
Bituminous coal	205.300		0.000205300		10,138		2.08
No. 6 fuel oil	173.906		0.000173906		10,360		1.80
No. 2 fuel oil	161.386		0.000161386		10,360		1.67
Natural gas	117.080		0.000117080		10,389		1.22

*Assumes steam turbine electricity production
Source: www.eia.doe.gov

The average number of pounds of CO_2 emitted per kilowatt-hour (kWh) of electricity generated in the United States by the electric power sector from 2000 to 2008 with all types of generators is: coal, 2.17; natural gas, 1.06; petroleum, 1.94.

The electric power sector comprises electricity-only and combined-heat-and-power plants whose primary business is to sell electricity, or electricity and heat, to the public. The data is for all the different types of generators used by the electric power sector during those years. The average amount of CO_2 for all the electricity generated in the United States by the electric power sector in 2008 was about 1.312 pounds per kWh.

To derive a factor for the electricity that you use, you have to account for transmission and distribution losses by multiplying the emissions factor by 1.065. For example: 1.312 x 1.065 = 1.396 pounds of CO_2 per kWh. Note that there can be significant variation in the CO_2 content of electricity between locations and time of day due to variation in generation sources and dispatching to the grid.

The EIA has data on historical annual data generation by fuel and energy type and CO_2 (and SO_2 and NO_x) emissions for each state in State Electricity Profiles at: www.eia.doe.gov/cneaf/electricity/st_profiles/e_profiles_sum.html.

Some states, such as California, are net importers of electricity from other states, so the electricity generated in the state may not reflect the sources of all the electricity consumed in the state.

Paul Hesse • U.S. Energy Information Administration, Washington, DC

MisLED

There are many LED distributors and manufacturers out there—some are good and some bad; some change, others don't. Many products are unbranded, and manufacturers and distributors sometimes blame each other for failures resulting in customers left holding bad merchandise.

There has been chatter about problems with LEDs and refunds through some companies, so be sure to check your source before purchasing.

It's still the wild west—like CFLs a decade ago and solar 30 years ago.

Mike Cohn • via e- mail

Clarification

Regarding "Getting Out of Trouble" (*Ask the Experts, HP136*) Renewable Energy Corp. (REC) has completed repairs to junction boxes on all modules (serial numbers containing "REC SCM") sold to North America in 2008. This repair program is complete and no other REC modules are affected.

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Ask the EXPERTS!

Change Battery Voltage?

I live off-grid and my 8-year-old battery bank is not holding a charge the way it used to. I have three photovoltaic arrays (totaling 4,200 watts) feeding into three OutBack MX-60 charge controllers and a 24-volt bank of 16 Surrette batteries (350 amp-hours each).

My question is, when I replace the battery bank, what are the benefits of moving to a 48-volt system? Also, can my array support a bigger battery bank than I currently have? I have a Trace 4024 inverter and a 10 kW backup generator that runs about 400 hours per year. I'd like to reduce the generator run time.

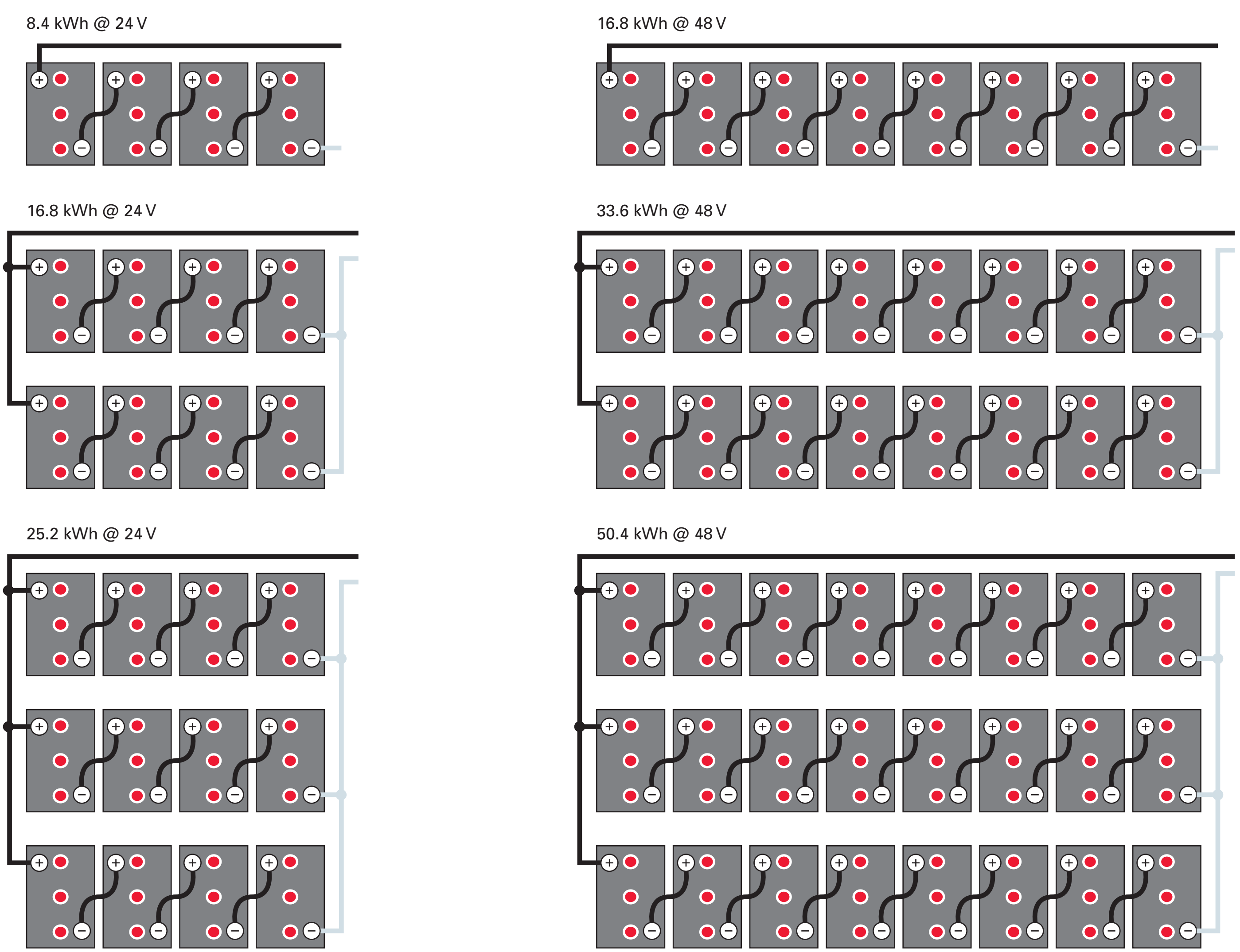
Bill Zorr • via e-mail

Upgrading to a 48 V system means that you will have to replace your 24 V inverter, but higher battery bank voltage does offer some advantages:

- You can have the same capacity of battery bank with fewer series strings, which means a better distribution of charge across the battery bank.
- The amperage in the battery cables will be lower, which means less voltage drop. Or, if you replace the original cables, smaller cable diameter and/or longer battery cable length is now an option.
- At higher battery bank voltages, higher-wattage inverters/battery chargers are available, which also provide a higher rate of charging from a generator (using more of its capacity, reducing generator run time and thereby saving fuel).

In most places in the United States, a 4,200 W PV system would give you about 17 kWh per day on average. You want your batteries to be completely recharged every three to four days. On average, the incoming energy should roughly equal the outgoing. But to advise you on battery size without considering consumption would be an error. The correct way to size the battery bank is to work from consumption and take into account inverter efficiency (usually estimated at 90%), days of autonomy (usually three to five days), and permissible depth of discharge (usually 50%).

For instance, assuming 90% inverter efficiency, three days of autonomy, and 50% depth of discharge, the battery bank would be



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$2.57 /Watt
$579.15 ea
(pallet pricing)
Yingli Solar
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$2.30 /Watt
$517.50 ea
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6.7 times larger in kWh than the average daily consumption. This may require you to use a higher-capacity battery, as opposed to more of the same batteries. However, larger-capacity, industrial-type batteries can be large (and very heavy) and difficult to maneuver, so if that is an issue, then you could look to reduce your consumption and use the generator run time more productively by doing high-energy tasks while the generator is running or while the sun is shining (since the array is large).

Changing your battery bank to 48 V will allow you to get more batteries in the bank. Here's why: The recommended number of series-connected strings in a battery bank is maxed at three so that charging across all cells is about the same. So at 48 V, more batteries can be combined to make a higher-capacity battery bank.

In your case, for a 48 V battery bank, there would be eight batteries per string (using 6 V batteries). With three strings permissible, 24 batteries could be easily combined for a total of 1,050 Ah (3 strings x 350 Ah = 1,050 Ah). This 1,050 Ah battery bank at 48 V would contain 50.4 kWh.

There is also a disadvantage to higher battery voltage. The higher battery bank voltage will increase the number of batteries in series, making it more difficult to get the capacity you want if using a particular battery—the ideal may fall between two possible configurations.

Here's an example: If you were to configure a battery bank for 24 V with L-16 type batteries, (350 Ah at 6 V each), your choices are between an 8.4 kWh, 16.8 kWh, or 25.2 kWh. (This equates to 350 Ah, 700 Ah, or 1,050 Ah at 24 V.) If you were to configure the bank for 48 V, the choices are 16.8 kWh, 33.6 kWh, and 50.4 kWh (This equates to 350 Ah, 700 Ah, or 1,050 Ah at 48 V.) So you just have to run the numbers to see if a 48 V battery bank will serve your needs. Of course, other batteries with different capacities are available that might fill in the gaps.

Your system's generator is larger than your inverter's battery charger can handle. The good ol' Trace SW4024 has a 120 A battery charger, which translates to only 2,880 W of battery charging, maximum. So unless you run other loads on your generator while you are charging, you are wasting a lot of fuel.

Additionally, AC generators larger than 3 kW usually have 240 V output. If you are only charging through the Trace SW4024 inverter, you are only using one leg (120 V) of the generator's output. Generators that run "unbalanced" like this won't last as long as when they run balanced loads.

You can get longer generator life and more charging by:

- Installing a second battery charger that is connected to the other leg of the generator. This would make better use of the generator's output and help balance the amperage on the legs of the generator.
- Adding a 120/240 step-down autotransformer, a second inverter or switching to an inverter that charges from 240 VAC.

So to recap, changing your battery bank voltage will require changing the inverter, but can help by giving you a larger battery capacity. To size the battery bank you must start with consumption. And to

reduce generator run time (and increase its longevity), charge off both legs of the generator.

Kelly Larson • www.solarkelly.com

SHW Pipe Insulation

For several years, I've been getting solar-heated water from my self-installed system, with only one complaint. I used the common, "cheap" grey-foam pipe insulation, but after a couple of years of weather exposure, it disintegrates, and it melts when the water temperature reaches 200°F. I'm looking for the good stuff that can endure the weather and withstand higher pipe temperatures. What is it called, and who sells it?

Paul Melanson • Dartmouth, Nova Scotia

The insulation you want is high-temperature closed-cell pipe insulation, and is sold under the brand names of Halstead pipe insulation, Rubatex (also sold as Insul-Tube), AP Armaflex, and K-Flex. All of the closed-cell insulations are rated for 220°F, the minimum continuous service temperature for collector loop insulation specified by the Uniform Solar Energy Code. Home centers and hardware stores that I am familiar with don't stock this specialized insulation. If you don't live near a major city, you may have to order it online.

Any exterior insulation should be protected from the elements with aluminum wrap, aluminum tape, or other suitable material. One very durable method I've seen is to sleeve the insulated pipe in 2-inch ABS (plastic drain) pipe.

Chuck Marken • Solar Thermal Editor

Right: Wrapping SHW piping in high-temperature, closed-cell insulation. Below: The same insulated pipe, sleeved in ABS plastic to protect it from the elements.

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2010 WIND GENERATOR buyer's guide

by Ian Woofenden & Mick Sagrillo

Courtesy Bill Court

Looking for the perfect antidote to your static solar collectors? Want something that *moves*, letting you know that it's working? If you're ready and your site is right, you could consider a wind-electric system.

Be forewarned that when it comes to maintenance, challenges, and spectacular failures, wind-electric systems are anything but "upkeep-free" or simple. But if you make good decisions up front and stay on top of maintenance and repair, your wind-electric system should provide years of energy for your home or business.

Read on for some perspective on the three most common mistakes to avoid and the three most important decisions you need to make. Then take a look at the equipment available today, and learn more about making a wise buying decision.

How High?

The most common mistake made with small wind-energy systems is putting a turbine on too short of a tower. As with any renewable electricity system, the collector must have good access to the fuel—it needs good wind, which is somewhat different than other renewable sources. The power available in the wind increases with the cube of the wind speed. This means that there is nearly 100% more power available in 10 mph winds than in 8 mph winds.

While we might perceive some puffs and gusts at ground or rooftop level, there is little usable fuel at these heights. The rule used by experienced wind installers is to place the whole rotor at least 30 feet above any obstacle (usually trees) within 500 feet of the tower or the prevailing tree line, whichever is higher. Keep in mind that you are installing the wind turbine for decades of productivity—trees your turbine may barely clear today may be considerably taller in several years. Get it right at installation time by estimating mature tree growth and sizing the tower accordingly.

In addition to access to winds of sufficient quantity, the 30-foot rule also gets the turbine rotor above much of the turbulence created by any nearby obstructions. While turbulent winds are reduced-quantity winds, they are also reduced-*quality* winds, putting considerable stress on a wind turbine by their constant buffeting and shifting. Turbulence's continuous pounding strains all wind turbine components, adding to maintenance requirements and reducing the equipment's life.

These two wind turbines on very short towers underperform because they are below the area's tree line and very close to obstructions.

Short towers result in a quadruple whammy: Reduced wind speeds, more wear and tear from turbulence, less electricity, and compromised reliability.

How Wide?

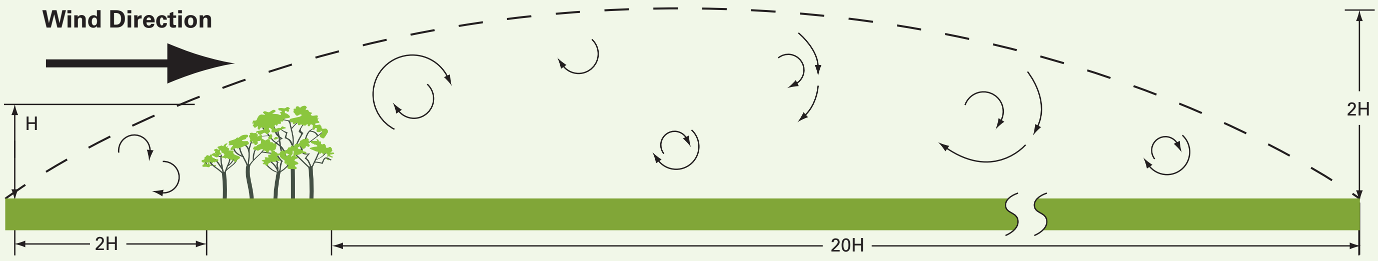
Your wind generator's "swept area" defines its ability to collect wind, which is, after all, the resource you are trying to tap. Like other renewable technologies, a small collector will collect a small amount of energy; a large collector will collect a large amount of energy. If you're trying to capture enough rainwater to supply your household, water the garden, and wash the cars, you don't try to collect it in a thimble. And in the same way, you need an adequate "wind collector" to make the amount of energy you need.

Typical small wind turbines that can contribute substantially to a home, farm, school, or business will be 12 to 70 feet in diameter. In our list, we've included a few machines that are smaller, but remember that you might not get the energy you need out of these machines.

There's no magic behind the blades of your wind generator that can make dramatically more energy from the same swept area. There's no substitute for square footage of swept area—the area of the wind that is intercepted by the rotor.

Wind Turbulence

Turbulence slows and degrades the wind resource, both upwind and downwind of obstructions. Note the height (H) and distance of turbulence behind an obstruction—an unsuitable area for a wind turbine.



Bergey Windpower's XL.1 is the smallest turbine listed in this guide, with a rotor diameter of 8.2 feet.

Courtesy www.bergey.com

Courtesy www.northernpower.com

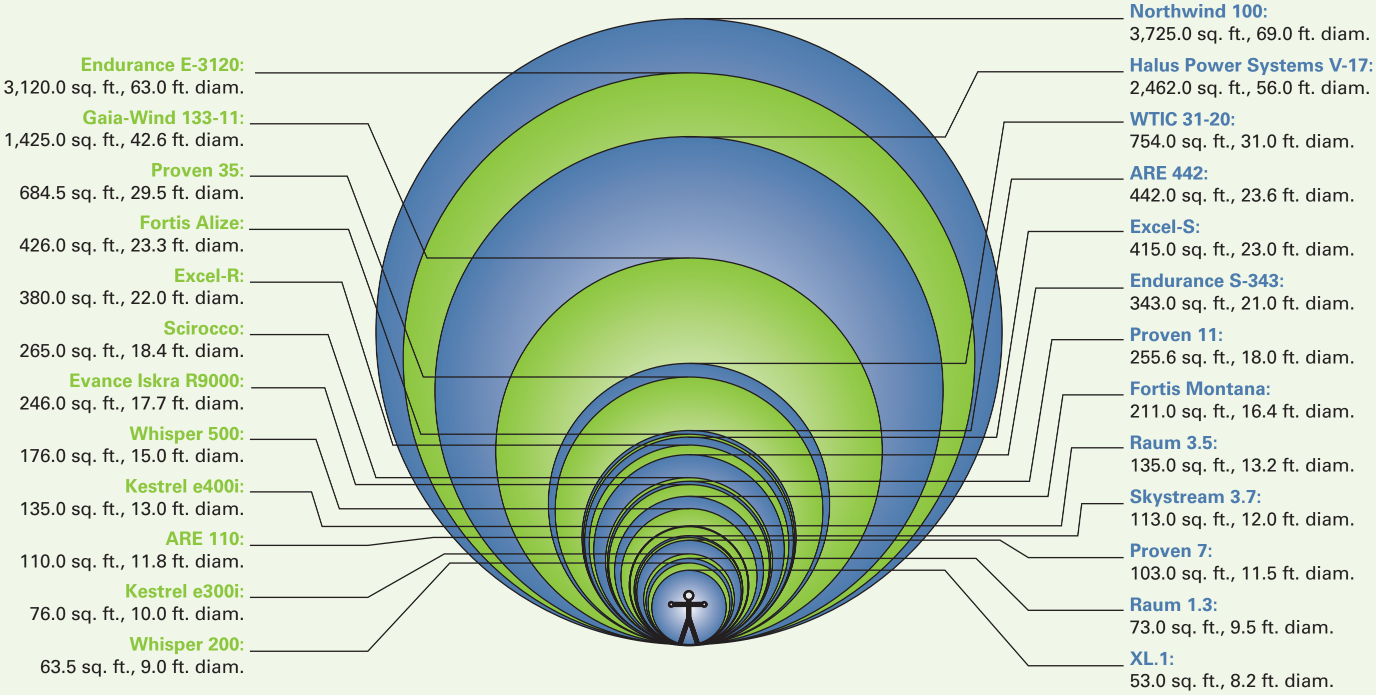
The Northern Power Northwind 100 turbine is the largest turbine included in this guide, with a 69-foot-diameter rotor.

How Robust?

You want your wind turbine up high *and* to have resilience to stay in the game for the long haul. Too many whizbang wind generators advertise their unique features, but only years of enduring tough conditions on tower tops will reveal a machine's durability and reliability.

You'll want the manufacturer you purchase from to have some depth, too—a long history in the business of designing, manufacturing, and supporting wind-electric systems. In our nearly 60-plus combined years of connection with the small wind industry, we've rarely seen a "new breakthrough" product actually deliver on its promises. Call us skeptics, but we'll wait until a company has depth in the marketplace—machines running for three to five years—before we even start to get interested.

Blade Diameters & Swept Area



Wind journalist Paul Gipe wisely notes that efficiency, price, and peak power are meaningless without durability. A machine can be "engineered," "an advance in technology," and "spectacular" in the advertisements, but when it dies on the tower or falls off the tower, all "advancements" and claims are meaningless—a non-operational wind turbine is a rather expensive piece of kinetic sculpture at best.

Wind System Sizing Process

A simplified wind-electric system design process looks like this:

- Determine your energy need (kilowatt-hours; kWh) per day, week, or year) and try to reduce it via energy efficiency and conservation.
- Decide on your tower height using the 30-foot rule and estimated mature tree height—remember, a turbine on a taller tower will always generate more electricity than one on a shorter tower.
- Estimate your resource—the average wind speed at proposed machine height.
- Determine rotor diameter, based on predicted kWh at your site's average wind speed.
- Compare all of the products in the rotor diameter range you have selected. Consider a larger turbine if your needs will grow, or a small turbine if you will be downsizing your consumption.
- Choose a specific wind generator.
- If an off-grid system, choose balance-of-system (BOS) components—inverter, batteries, etc. Grid-tied systems without battery backup are usually package systems: turbine, controller, and inverter are matched and specified by the manufacturer.

It's just plain foolish to select your wind generator *before* you've done the basic groundwork of determining your energy load, tower height, and wind resource—you'd need to be very lucky to guess right. You might end up buying a wind generator that's too small, resulting in a disappointing investment. Wind isn't incremental like PV—you cannot add generating capacity to an existing system; you're stuck with what you installed. Upgrading to a larger wind generator will mean buying a stouter tower along with pouring a new foundation. It may also mean larger BOS components.

On the other hand, buying a wind generator that's too large isn't the worst problem to have, since it will result in more energy than you really need, which you'll likely find a use for. But you run the risk of spending more money than you need to, so get the data first and make wise design choices up front.

To make your decision based on cost alone is downright unwise. A cheap wind turbine that is half the price of the quality option—but only lasts two or so years—is the most expensive electricity you can buy.

Wind Turbine Specifications

The table shows basic specs for small wind turbines available and supported in North America. Understanding the specs will help you make intelligent choices when it's time to buy your turbine.

Manufacturer/importer. The wind turbines listed are either new, remanufactured (in one case), or imported. For imported models, the North American contact is listed.

Swept area is the area in square feet of the wind "swept" by the rotor. This is the size of the "wind collector," and besides your average wind speed, is the single largest factor influencing turbine output. A larger rotor will give you more energy, all other things being equal (and they generally are).

Rotor diameter is another identifier for turbines, along with swept area, but you should pay attention here. The difference between a turbine with an

(continued on page 52)

Southwest Windpower Whisper 200

Courtesy www.windenergy.com

Raum Energy Raum 1.3

Courtesy www.raumenergy.com

Kestrel e300i

Courtesy www.kestrelwind.co.za

Proven Energy Proven 7

Courtesy www.provenenergy.co.uk

Courtesy www.cascadewindcorp.com

Courtesy www.windenergy.com

Courtesy www.kestrelwind.co.za

Wind Turbine Specifications

Manufacturer	Bergey Windpower	SW Wind Power	Raum	Kestrel	Proven Energy	Cascade Wind
Web site	www.bergey.com	www.windenergy.com	www.raumenergy.com	www.kestrelwind.co.za	www.provenenergy.co.uk	www.cascadewindcorp.com
Model	XL.1	Whisper 200	Raum 1.3	e300i	Proven 7	ARE110
Swept area (sq. ft.)	53.0	63.5	73.0	76.0	103.6	110.0
Rotor diameter (ft.)	8.2	9.0	9.5	10.0	11.5	11.8
Tower-top weight (lbs.)	75	65	86	165	420	315
Predicted annual energy output (kWh)						
8 mph	420	794	908	973	1,704	1,629
9 mph	610	1,121	1,110	1,315	2,438	2,274
10 mph	840	1,483	1,539	1,726	3,494	3,039
11 mph	1,110	1,865	2,004	2,131	4,417	3,894
12 mph	1,400	2,254	2,479	2,551	5,627	4,801
13 mph	1,710	2,637	2,940	2,966	6,614	5,728
14 mph	2,040	3,005	3,365	3,356	7,842	6,643
Rpm	490	900	800	600	300	310
Generator type	PM	PM	PM	PM	PM	PM
Governing system	Side furling	Angle furling	Tilt-up furling	Blade pitch	Blade pitch	Side furling
Governing wind speed (mph)	29	26	23	24	27	25
Shutdown mechanism	Dynamic brake	Dynamic brake	Dynamic brake	Dynamic brake	Disc brake	Dynamic brake
Batteryless grid-tied version	Pending	No	Yes	Yes	Yes	Yes
Battery voltages	24	24, 36, 48	24, 48	12, 24, 48	24, 48	48
Controls included	Yes	Yes	Yes	No	Yes	Yes
Tower or installation included in cost	No	No	No	No	Tower (30 ft.)	No
Cost: batteryless version	—	—	$3,650	$6,440	$25,000	$12,650
Cost: battery charging version	$2,790	$3,405	$3,650	$4,138	—	$11,800
Warranty (years)	5	5	5	5	5	5


Raum Energy
Raum 3.5
Courtesy www.raumenergy.com

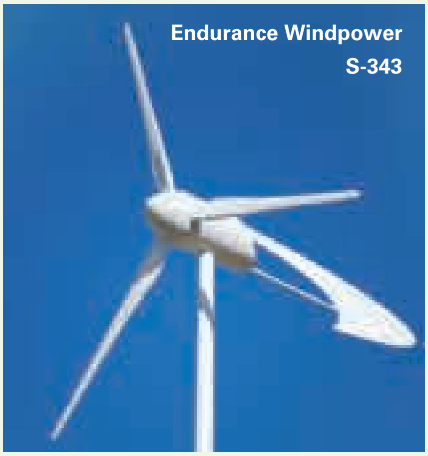

Southwest Windpower
Whisper 500
Courtesy www.windenergy.com


Fortis
Montana
Courtesy www.fortiswind.com

	SW Wind Power	Kestrel	Raum	SW Wind Power	Fortis	Evance	Proven Energy
	www.windenergy.com	www.kestrelwind.co.za	www.raumenergy.com	www.windenergy.com	www.fortiswind.com	www.evancewind.com	www.provenenergy.co.uk
	Skystream 3.7	e400i	Raum 3.5	Whisper 500	Montana	Iskra R9000	Proven 11
	113.0	135.0	135.0	176.0	211.0	246.0	255.6
	12.0	13.0	13.2	15.0	16.4	17.7	18.0
	170	331	170	155	440	660	1,323
	914	2,010	2,021	1,474	3,459	3,500	2,773
	1,373	2,781	3,213	2,139	4,438	5,030	3,973
	1,925	3,807	4,380	2,907	5,443	6,670	5,752
	2,594	5,050	5,811	3,749	6,444	9,012	7,358
	3,216	5,996	7,447	4,637	7,410	10,590	9,526
	3,898	7,230	8,631	5,544	8,315	12,530	11,331
	4,575	8,285	10,272	6,445	9,132	14,500	13,606
	330	500	350	325	400	230	200
	PM	PM	PM	PM	PM	PM	PM
	Dynamic brake	Blade pitch	Active brake	Angle furling	Side furling	Blade pitch	Blade pitch
	28	24	35	27	25–30	134	27
	Dynamic brake	Dynamic brake	Dynamic brake	Dynamic brake	Electric Braking	Electrodynamic Brake	Disc brake
	Yes	Yes	Yes	No	Yes	Yes	Yes
	—	48	24, 48	24, 36, 48	48	24 – 300	48
	Yes	No	Yes	Yes	Yes	MPPT	Yes
	Tower (33 ft.)	No	No	No	No	Tower (50 ft.)	Tower (30 ft.)
	$9,695	$13,328	$7,000	—	$15,800	—	$38,000
	—	$11,178	$7,000	$8,795	$15,800	$18,800	—
	5	5	5	5	5	5	5

Wind Turbine Specifications (continued)

Manufacturer	Eoltec	Endurance Windpower	Bergey Windpower	Bergey Windpower	Fortis
Web site	www.eoltec.com	www.endurancewindpower.com	www.bergey.com	www.bergey.com	www.fortiswind.com
Model	Scirocco	S-343	Excel-R	Excel-S	Alize
Swept area (sq. ft.)	265.0	343.0	380.0	415.0	426.0
Rotor diameter (ft.)	18.4	21.0	22.0	23.0	23.3
Tower-top weight (lbs.)	450	600	1,050	1,050	847
Predicted annual energy output (kWh)					
8 mph	3,496	5,249	3,600	5,000	11,098
9 mph	4,997	7,293	5,400	7,100	14,659
10 mph	6,746	9,498	7,500	9,600	18,456
11 mph	8,687	11,781	9,700	12,700	22,344
12 mph	10,751	14,065	12,100	15,900	26,156
13 mph	12,870	16,282	14,500	19,500	29,728
14 mph	14,983	18,375	16,800	23,300	32,925
Rpm	245	166	310	240	300
Generator type	PM	Induction	PM	PM	PM
Governing system	Blade pitch & stall regulation	Stall regulation	Side furling	Side furling	Side furling
Governing wind speed (mph)	26	—	33	32	25–30
Shutdown mechanism	Dynamic brake (opt. blade pitch)	Disc brakes	Crank out tail	Crank out tail	Electric braking
Batteryless grid-tied version	No	Yes	No	Yes	Yes
Battery voltages	—	—	24, 48, 120, 240	—	48
Controls included	Yes	Yes	Yes	Yes	Yes
Tower or installation included in cost	No	Tower (120 ft.)	No	No	No
Cost: batteryless version	$29,130	$35,000	—	$29,500	$31,100
Cost: battery charging version	—	—	$24,750	—	$31,100
Warranty (years)	5	5	10	10	5



Courtesy www.endurancewindpower.com

Courtesy www.bergey.com

Courtesy www.bergey.com

Cascade Wind	Proven Energy	WTIC	Gaia-Wind	Halus Power Systems	Endurance Windpower	Northern Power Systems
www.cascadewindcorp.com	www.provenenergy.co.uk	www.windturbine.net	www.gaia-wind.com	www.halus.com	www.endurancewindpower.com	www.northernpower.com
ARE442	**Proven 35**	**31-20**	**133-11**	**V-17**	**E-3120**	**Northwind 100**
442.0	684.5	754.0	1,425.0	2,462.0	3,120.0	3,725.0
23.6	29.5	31.0	42.6	56.0	63.0	69.0
1,600	2,424	2,500	1,984	17,000	8,800	16,100
7,081	10,759	7,295	11,535	37,820	48,145	49,099
9,910	14,826	10,689	17,004	54,966	68,890	69,742
13,198	20,400	14,966	22,962	75,165	91,758	98,996
16,819	25,057	20,066	29,127	97,850	115,746	124,508
20,628	30,895	25,836	35,263	122,375	139,955	158,135
24,483	35,448	32,070	41,167	148,090	163,647	185,793
28,267	40,863	38,552	48,676	174,371	186,254	220,558
150	150	175	56	50	41	Variable 30-60
PM	PM	Brushless alternator	Induction	Induction	Induction	PM
Side furling	Blade pitch	Blade pitch/side face	Stall-regulated airfoil	Motor yaw	Stall-regulated	Electronic stall & dump load
25	25	25.5	—	—	—	—
Dynamic brake	Disc brake	Disc brake	Disc brake	Disc brakes & active yaw	Disc brakes & pitch control	Dynamic & disc brakes
Yes	Yes	Yes	No	Yes	Yes	Yes
—	48	—	—	—	—	—
Yes	Yes	Yes	Yes	Yes	Yes	Yes
No	Tower (50 ft.)	No	Tower (60 ft.) & foundation	No	—	Tower (120 ft.)
$39,600	$79,000	$43,225	$51,652	$110,000	$250,000	$475,000+
—	—	—	—	—	—	—
5	5	1 (5 optional)	2 (5 optional)	1 (5 optional)	5	2 (3+ optional)

Courtesy www.fortiswind.com

Courtesy www.cascadewindcorp.com

Courtesy www.provenenergy.co.uk

Courtesy www.windturbine.net

8-foot diameter and one with a 10-foot diameter might not seem large, but the 25% increase in diameter represents a 56% increase in collector size, with a proportional increase in energy output.

Tower-top turbine weight may give you an idea of turbine durability. Although weight itself doesn't necessarily translate into turbine longevity, a heavier turbine often means a more durable machine.

Predicted annual energy output (AEO) at 8 through 14 mph gives you some general numbers to match to your site's average wind speed and energy needs. Note that all AEOs provided in the table were supplied by the manufacturers. Your turbine's performance at your site may be lower, sometimes significantly. To be conservatively cautious, you may want to multiply the AEOs listed by about 75%. We have no evidence that all manufacturer AEOs are overstated, although some seem to be. It would certainly be better to underpredict AEO and be pleasantly surprised with more electricity than to overpredict AEO and be disappointed.

Be conservative by choosing the next larger turbine when you're not sure of your exact energy use, if the exact size of turbine you need is not available, or if your confidence of your site's average wind speed is shaky. Also, AEOs apply to locations from sea level to 1,000 feet in elevation and must be adjusted for lower air density at higher altitudes. Your installer or turbine manufacturer can help you crunch these numbers.

Rpm is the blade revolution speed at the turbine's rated output. It relates to two characteristics of wind generators: durability and sound production. A slower rotor speed in a given class of turbines will generally mean a longer-lasting turbine—less wear and tear on the rotating parts and less centrifugal force trying to tear the rotor apart. It also usually means a quieter turbine. Note that lower rpm does not mean lower production, nor does higher rpm mean higher production. In both cases, the alternator rpm is matched to the rotor speed to get as much energy out of the wind as possible.

Generator type has to do with how the wind system is interfaced to the utility in grid-tied systems. Permanent-magnet and brushless alternators must interface with the utility through a synchronous inverter with anti-islanding protection. Induction machines do not need inverters, but have their own specialized "controllers" for utility interconnection. In either case, the inverter or controller are specifically matched to the wind turbine and sold with it.

Governing system describes the method the turbine uses to shed excess energy in high winds to protect the turbine from overspeed. Some turbines tilt or "furl" the rotor directly up or to the side, while others furl at an angle. Others use blade pitch control, turning the blades out of their optimum aerodynamic angle so that they don't capture as much energy. Induction machines typically use "stall-regulated blades," meaning they lose aerodynamic lift as the wind speed increases beyond a safe rpm. Blade pitching more reliably protects the wind generator. Due to more moving parts and greater complexity, machines that have this feature cost more than machines that furl or stall regulate.

Governing wind speed is the point at which the turbine starts governing. This is really a range of wind speeds depending on circumstances, and not usually one given wind speed for any given turbine, but convention dictates listing one wind speed. A low governing speed suggests that the turbine designer was conservative, preferring a long-lasting turbine over high peak production in the rare times of high winds. A higher governing wind speed indicates that the turbine may eke out a bit more energy in infrequent and potentially dangerous wind speeds.

Shutdown mechanism refers to the method used to stop the turbine for service, in an emergency, or when you just don't need the energy or want the turbine to run—when on vacation or before an approaching storm, for example. Many smaller turbines have no mechanical means to shut them down. Instead, they rely on dynamic braking (electrical shorting of the windings), which may or may not work in higher winds, depending on the design. Mechanical brakes are usually more reliable than dynamic braking, under which "electric braking" and

"electrodynamic brake" fall. Generally, larger and more expensive wind turbines have more reliability and redundancy built into their shutdown mechanisms and may use more than one braking method.

Batteryless grid-tied tells whether the turbine is available in this configuration—normally the most cost-effective choice. Most systems are configured to be connected to a standard 120 or 240 VAC single-phase utility service connection. A few (typically the larger turbines) are available for connection to a three-phase utility service—this is noted in the AEO row of the table.

If you're determined to have backup for utility outages, some battery-charging turbines can be grid-tied via a battery-based inverter that also synchronizes its output with the utility grid. Check with the manufacturer.

Battery voltages are listed for battery-charging turbines, so you can choose the right turbine voltage for your battery bank. Most modern, whole-house, battery-based RE systems use a 48 V battery bank with an inverter to supply the house with 120 or 240 VAC.

Controls included lists what you get when you buy an off-grid turbine—components such as a controller, a dump load, and metering. If they are not included, don't forget to add them into your cost estimates—these components can be expensive. Grid-tied wind systems are usually sold as a package, with the wind turbine, controls, and inverter.

Cost is the MSRP for the turbine and any included controls or inverter. Remember that the turbine is only one component in the system—and usually not the most expensive one. For smaller systems, a tower can easily exceed the turbine cost. Off-gridders need to include the cost of batteries and inverter. And don't forget the other installation costs: excavation for the foundation; concrete and rebar; possible crane costs; wiring and all electrical components; shipping; taxes; and labor, if the job is contracted. Note that some turbines include tower, wiring, installation materials, and labor costs.

Warranty is an indication of the manufacturer's confidence in the machine, or is set to meet the requirements for state incentive programs. Find out what is covered—usually it's equipment only, and not the costs of replacement shipping or labor, which can be significant. Several of the manufacturers that offer shorter than five-year warranties will extend the warranties for an additional cost.

Understanding Rated Output

"Wind turbine rated output" or "rated kW" is the most misunderstood specification. Unlike PV module ratings that are standardized at 1,000 watts per square meter at 25°C, small wind turbines have no such standard. As a result, one wind turbine might be rated at 10 kW in a 25 mph wind; another might carry the same rating—but at 32 mph. Because the power available in the wind increases with the cube of the wind speed, a turbine rated at 10 kW at 32 mph is analogous to only a 5 or 6 kW turbine rated at 25 mph. In addition, your turbine will see *neither* of these speeds often since the most common wind speeds for residential systems are 10 to 20 mph, with the latter seen only a very small percentage of the time. That's why using rated power as a performance measure is deceptive at best.

Our advice is to ignore the kW rating for wind turbines—unless you are a wind techie using them to categorize physical sizes of the equipment. Instead, look for documentation of the turbine's annual energy output (AEO). Since you are likely to install only one wind turbine, it makes sense to shop for a turbine that will generate the amount of electricity you need each year. The kW rating does not—and cannot—tell you this.

The American Wind Energy Association recently developed a standard for small wind turbines to meet when marketed. In addition to the most important measure—AEO—the standard will include a kW rating, but not at an arbitrary wind speed. The new standard follows the European standard, and turbine kW rating will be at 25 mph (11 m/s). Including the AEO rating will put all turbines on a level playing field once manufacturers certify their turbines to the standard.


Gaia Wind 133-11

Courtesy www.gaia-wind.com


Halus Power Systems V-17

Courtesy www.halus.com


Endurance Windpower E-3120

Courtesy www.endurancewindpower.com

web extra

Learn more about wind-electric systems on our Web Extras page: **www.homepower.com/webextras**.

Reputation, Not Sales Pitch

A recent study indicated that there are at least 74 wind-turbine manufacturers in the United States offering products, plus a comparable number of non-U.S. companies that sell in the states. That same study also indicated that only 14 companies "have begun sales," meaning they actually have something to sell other than a computer simulation on their Web site, a prototype, or "vaporware." In other words, only one in five small-wind companies in the states really has a product that is available.

We have been criticized in the past for not including "this turbine" or "that company" in our coverage. We have included all of the U.S. and foreign firms that offer what we understand to be viable products from viable companies—turbines that might make good investments, and generate AEO as claimed.

Don't take our word for it—ask around. Seek out wind turbine owners, especially of the turbines you are interested in purchasing. What are the experiences of end users? A wind turbine is a major expense for most people. You are going to live with this system for the next 20 to 30 years, maybe longer. Would you pick a car off an Internet site without at least kicking the tires? Go out and kick some propellers—and see what will work for you.

Never buy a turbine solely on its up-front cost, but rather on what it will cost you over the long haul—in money, time, and aggravation. Wind-electric systems are the toughest renewable energy systems to maintain, with the highest failure rate. Why? Because wind turbines live in a brutal environment, atop 80- to 140-foot towers that are not readily accessible if you don't climb or if it's -30°F outside with a 30 mph wind howling. Avoid as much pain as possible by buying the highest-quality system you can afford.

Access

Ian Woofenden (ian.woofenden@homepower.com) lives with wind and solar energy, and appreciates reliability even more than he did when he was a young and foolish wind newbie.

Mick Sagrillo (msagrillo@wizunwired.net) is still learning about small wind—and not to stick his finger in the blades—after 30 years and hundreds of wind turbine installations.

Distributed MPPT

New Hardware to Maximize Module Output

by Justine Sanchez

Courtesy Michael Pendy

Even a small amount of shading can have a substantial effect on the output of a series string of PV modules. But distributed MPPT technologies are primed to minimize shading's impacts.

New equipment is showing up to address the limitations of standard single-inverter systems. Conventional batteryless grid-tied systems generally use a single maximum power point tracker (MPPT) that is housed in the inverter to condition the energy coming from multiple PV modules. The process tracks one maximum power point from array input, varying the ratio between the voltage and current delivered to get the most power it can.

But each PV module has differences that will cause it to have a *different* MPP than its neighbors. This can be caused by manufacturing tolerances; dust and dirt; different module temperatures; partial array shading; and so on. The result is that the array's MPP becomes a compromise between all the intermodule variances, and additional power that may be available from some modules (i.e., the unshaded, cleaner, cooler ones) is lost.

One solution is distributed MPPT (or "distributed power harvesting") equipment—electronic boxes, wired to individual PV modules, to independently track each module's MPP. This hardware can manipulate the maximum available power to deliver either a higher current or voltage, depending on the configuration of the system (series versus parallel wiring). Included in the category of "distributed MPPT" equipment are specialized DC-to-DC converters, microinverters, and AC modules (i.e., a microinverter packaged with a PV module and UL listed as a single product).

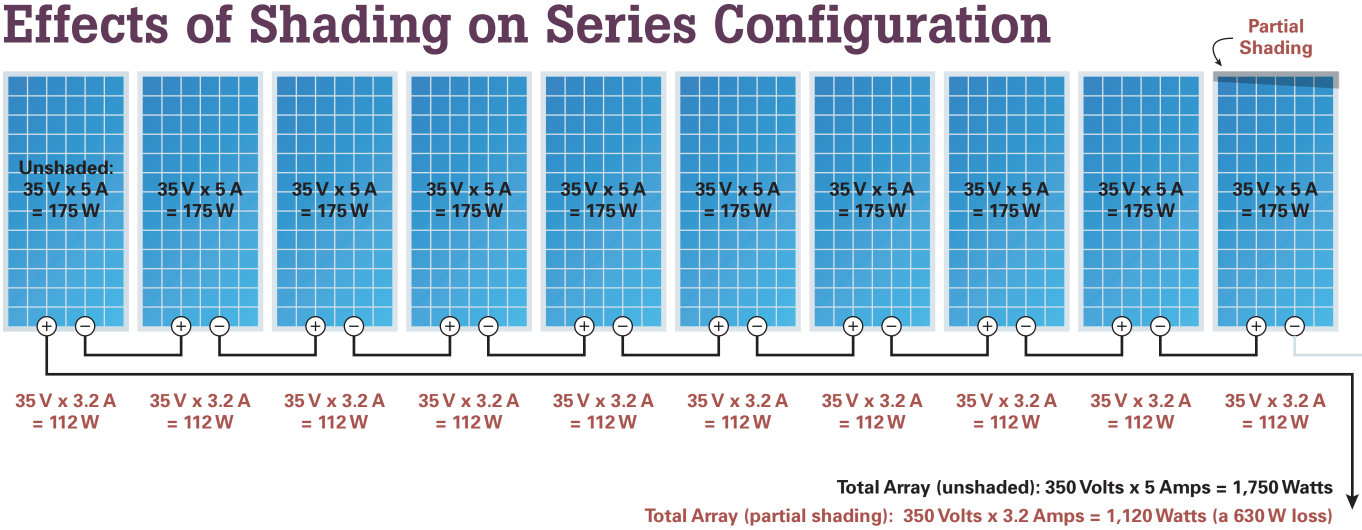
How They Work

To understand how these devices tap into power that might otherwise be lost, we need to understand a few rules about combining PV modules.

Individual, module-by-module power optimizers like this one by National Semiconductor can increase overall PV array production in cases of individual module underperformance.

Courtesy www.solarmagic.com

Effects of Shading on Series Configuration



Series configuration. When modules are wired in series, the voltage of each module is summed to obtain the total voltage of the string. The string's current will remain that of a single module. For example, let's say we have ten 175-watt modules in series—each at 35 V and 5 A.

Theoretically, the array should have 350 V and 5 A, or 1,750 W. However, what if each module's amperage isn't identical to the others, as would result if a module was partially shaded or in a different plane of orientation? When we wire dissimilar modules together in series, voltage will be additive. However, the current will be just above the *lowest* current in the string.

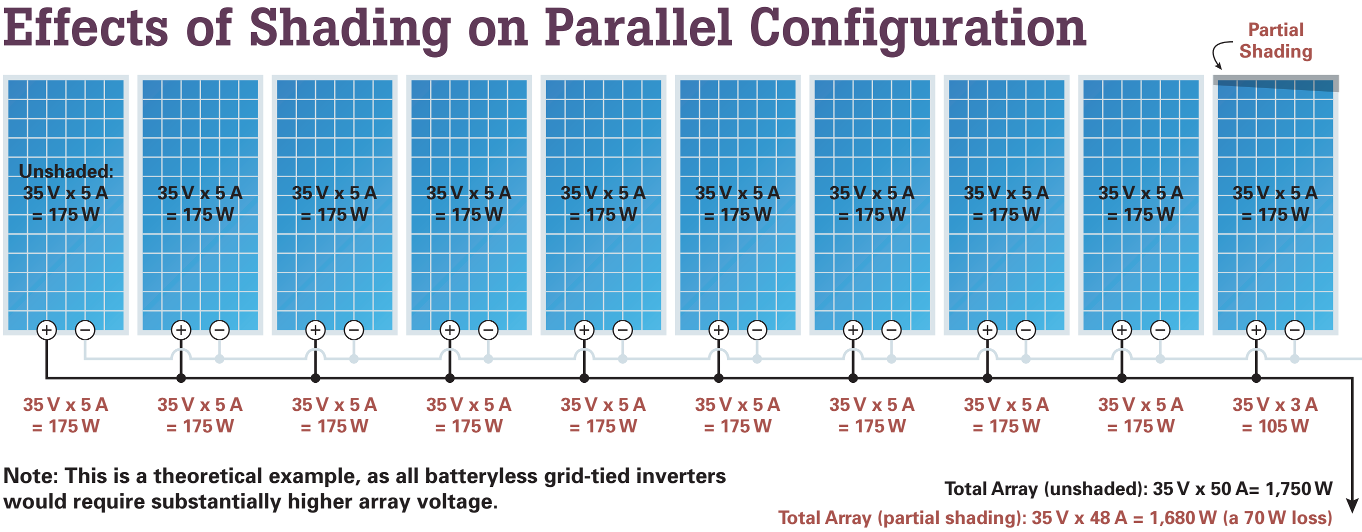
Let's say there were nine modules at 35 V and 5 A, but partial shading on the last module reduced its output to 35 V and 3 A. The resulting array's power would be about 350 V and 3.2 A, or 1,120 W. Notice the loss in the entire string (1,750 W – 1,120 W = 630 W) is much greater than the loss from the underperforming module (175 W – 105 W = 70 W).

Although this example is simplified, and bypass diodes on the array would keep the losses lower (see "Bypassing the Bypass" for more detail), the goal in a series configuration is to keep all the currents as equal as possible (discussed later)—or consider parallel wiring.

Parallel configuration. When modules are wired in parallel, the current of each module is summed, with the array's voltage remaining that of a single module. When dissimilar modules are wired in parallel, the amps add up, and the voltages will average. Wiring the same 10 modules in parallel results in an array that will have 35 V and 50 A, or 1,750 watts. But now, with the last module producing 35 V and 3 A, the resulting array's output would be about 35 V and 48 A, or 1,680 watts—a significant improvement over the series scenario.

Microinverters and some DC-to-DC converters (such as eIQ Parallux vBoost or Tigo Energy's Module Maximizer EP series) accommodate parallel configuration. But instead of leaving the module and array voltage low, they first boost the voltage to several hundred volts, proportionally reducing the current. Then, the high voltage (which has also been converted into AC in the case of the microinverter) and low current is wired in parallel. The result is that the shaded module is still able to contribute its full power, without affecting the rest of the array.

Effects of Shading on Parallel Configuration



Note: This is a theoretical example, as all batteryless grid-tied inverters would require substantially higher array voltage.

Bypassing the Bypass

The main article's simplified explanation of how distributed MPPT devices work left out an important detail: the module's built-in diodes (usually two or three that each control a section of the module) that help mitigate shading effects. While it's true that the lowest current will bog down a string of dissimilar modules in series, bypass diodes will help route power around a shaded module (or module section) once the resistance of the module's shaded section exceeds that of the diode.

Batteryless grid-tied inverters actually vary the load on the array to "activate" bypass diodes once the *array's* power loss due to a dissimilar module in series is greater than that module's (or module section's) loss. This is good news for systems without distributed MPPT—otherwise, a shaded cell could shut down an entire array.

Distributed MPPT equipment can recover the power from shaded modules (or module sections) and keep bypass diodes from activating, simply by finding the available peak current and voltage from the partially shaded module, then calculating and placing the required load on the module so that the current will still flow through the shaded portion of the module, instead of the bypass diode. This keeps module sections and entire modules from going "offline" so they still contribute what they can. This can be accomplished either via a parallel configuration where the module voltage is boosted to match the other module voltages and the available current is added to the total, or through a series configuration where the current of the shaded module is increased to match the other modules' currents.

A thin section of tape creates partial shading for testing two arrays—one with distributed MPPT, the other without.

Courtesy www.tigoenergy.com (3)

Distributed MPPT gains the bottom array an additional 412 watts (40% more output).

A test compared two rows of 11 modules: the bottom row has Tigo Module Maximizers-ES (series) units installed on each module, and the top row does not (see photo at left and screen shot, above). To mimic a shading scenario on both arrays, the two modules on the right have approximately 50% of the bottom row of cells covered. The screen shot shows the output of all modules under these conditions. The bypass diodes on both shaded modules in the top row (the non-Tigo string) have been activated—showing zero output. The remaining modules on the string have reduced output as well (about 116 W each). When the inverter varies the load on the array to activate the bypass diodes, the string is no longer operating at its maximum power point, reducing each module's output. In contrast, with the assistance of the Tigo devices, the bottom string is getting about two-thirds of the output from the shaded modules, and the other modules are operating at their maximum power (about 141 W each).

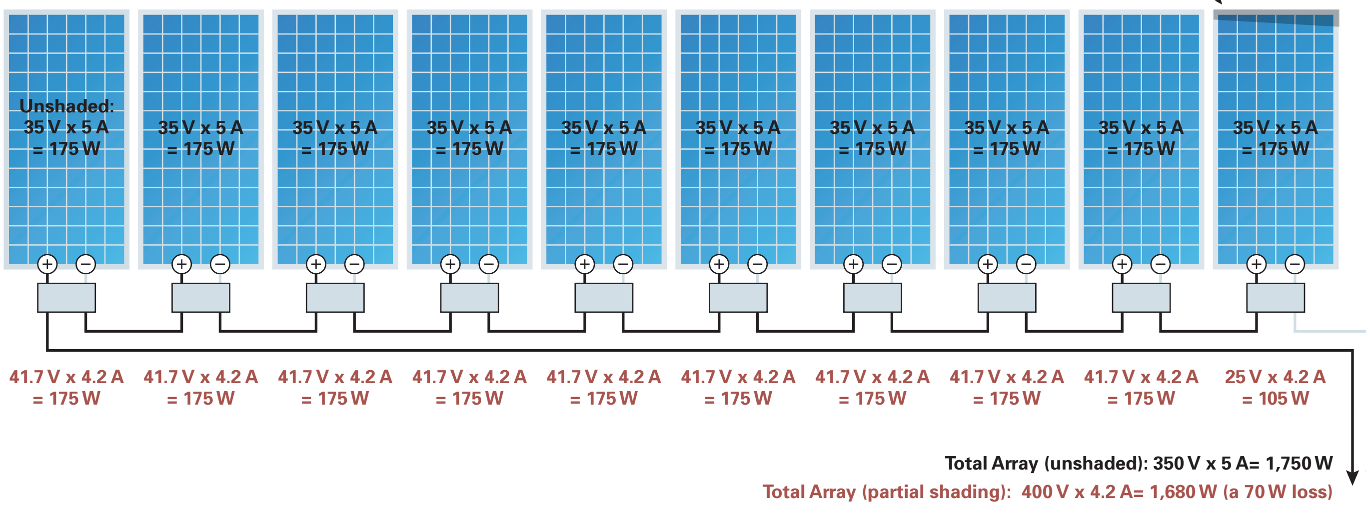
The length of time the unshaded modules on the non-Tigo string will operate at the reduced output depends on the inverter's MPPT algorithms. Inverters may scan the string periodically to find a new MPP. Another irradiance change (such as passing clouds) also can cause the inverter to search for the optimal peak power point for the unshaded modules and restore the output of those modules to their MPP. Even with distributed MPPT equipment installed, if entire PV cells have severe shading (opacity at 80% to 100%) and their is high irradiance, bypass diodes may still activate to prevent reverse current in the shaded module sections.

Per-module MPPT & series configuration. A distributed MPPT device wired to each module facilitates tracking the highest power point (voltage and current) for each module, but it can also manipulate that extracted maximum voltage and current to reduce potential string losses.

Although each maximization technology is a bit different for DC-to-DC converters, they all use DC-to-DC conversion circuits ("DC boost" raises voltage and lowers current, while "DC buck" drops voltage to raise current). Some solutions lower the voltage output of the weak modules, raising their current to match that of the stronger ones. Others raise the voltage of the stronger

Tigo Energy's hardware and software suite.

Distributed MPPT Effects on a Partially Shaded Series Configuration



modules, lowering the voltage of the weaker ones (buck/boost) to create a fixed string voltage and current.

In the example system, each module produced 35 V and 5 A (175 W), but the reality is that every module has a slightly different peak voltage and peak amperage. The MPPT adjusts the load for each module to find that per-module peak wattage. Then the maximum available power for the entire array (i.e., the sum of all the individual module's peak watts) can be harvested either in a parallel configuration, or in a series configuration by transforming the voltage to align the string current.

Although other factors, such as module production tolerance or temperature variances, can change a module's peak power output, let's continue with the simplified shading example (9 modules with 35 V, 5 A output, and one with 35 V, 3 A). The theoretical total watts available would be 1,680 W [(9 x 175 W) + 105 W]. Now, we can set the MPPT equipment output voltage to whatever we want and transform the voltage in the DC-to-DC device to set the current as well.

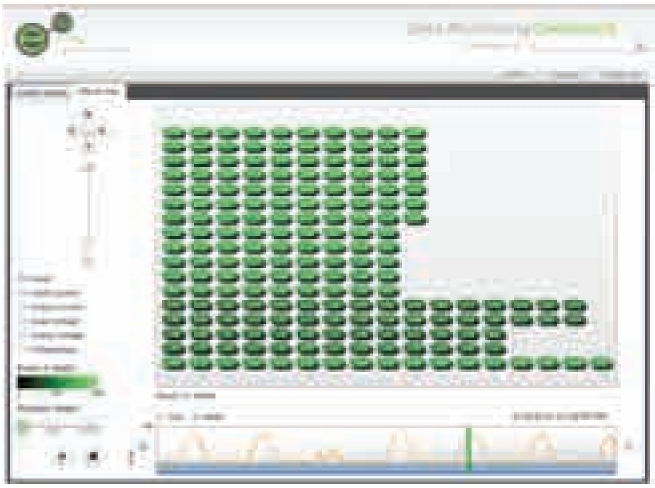
In the case of DC-to-DC converters using a series configuration, the output voltage can be set to one that is efficient for the centralized inverter. For example, the SolarEdge PowerBoxes are typically configured so that the total output voltage of the array (i.e. the inverter input voltage) is 400 V to work with their SolarEdge inverter. The output of each PowerBox is set to have a consistent amperage, and the summation of the voltages will equal 400 V.

Following our example: 1,680 watts ÷ 400 V = 4.2 A—this sets the current (amps) goal of each module/MPPT pair (for consistent amperage in series). Each PowerBox will alter output voltage to achieve 4.2 A. With the nine similar modules, voltage will be boosted to about 41.7 V (175 W ÷ 4.2 A = 41.7 V). The voltage of the PowerBox attached to the shaded module will be dropped to 25 V (105 W ÷ 4.2 A = 25 V).

A series configuration would yield 400 VDC at 4.2 A for 1,680 W [(9 x 41.7 V) + (1 x 25 V)], not including conversion losses, which are discussed later. Compare this to the 1,120 W that comes from this series configuration not using distributed MPPT equipment.

The values used in these examples are theoretical and do not account for the impact of bypass diodes (see "Bypass" sidebar). Explanations also are simplified. In reality, there are several ways to achieve this end result: For example, Tigo's equipment uses a technique called "impedance matching" via transistors, rather than directly alternating voltages.

eiQ Parallux vBoost units raise voltage and are wired in parallel to capture maximum power. Because these units can accept up to 350 W, more than one module can be wired to each unit.



Courtesy www.eiqenergy.com (2)

The SolarEdge PowerBox MPPT units are specifically designed to work with the SolarEdge inverter's voltage input window, increasing efficiency.

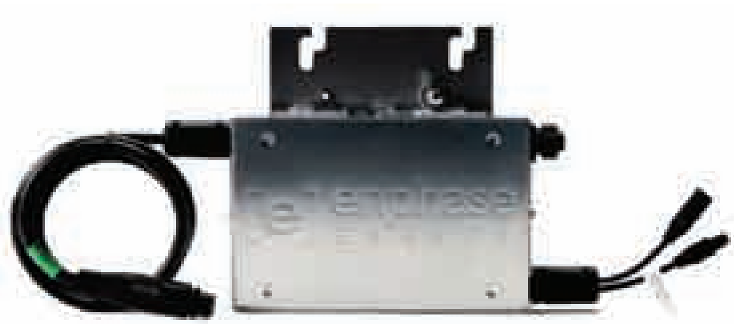
Courtesy www.solaredge.com (2)

Pros

Several of these products have added benefits, such as module-level monitoring (see the "Equipment" table). MPPT hardware attached to each individual module also can capture module performance data for monitoring each module in the array. Typically, this data is uploaded to the manufacturer's Web site via a separate systems communications box that is linked to an Internet gateway.

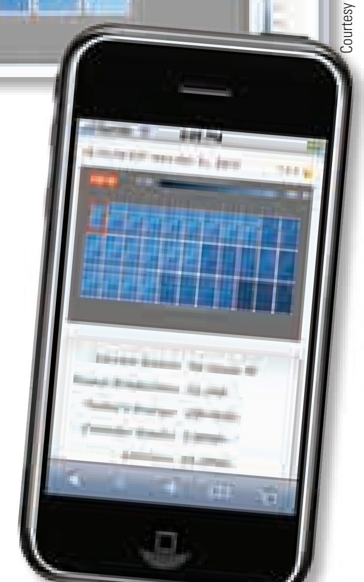
While module-level data monitoring is common for microinverter systems, when included with DC-to-DC converters, this feature also gives centralized inverter systems (for new systems *or* as a retrofit to older systems) the same capability. Monitoring each module's performance can help users quickly spot problems within the array. For example, a module with a bad diode (which can keep an entire section of a PV module from producing power) will be easy to spot. Without module-level monitoring, that problem would likely remain undetected.

Another feature available on some units is the ability to limit PV power at the array, remotely. Normally, PV arrays cannot be shut down when the sun is shining on them—even if you disconnect the balance-of-system equipment, high-voltage DC will still exist at the PV array, unless the modules are covered. With some distributed MPPT systems, commands can be issued to each box to disconnect each module from the next.



In systems utilizing DC-to-DC conversion, the voltage of an array normally operating at up to 600 VDC can be reduced to the voltage of a single module (from 17 to 70 VDC for crystalline PV modules), or less with some distributed MPPT equipment. The means for accomplishing this varies by product. For example, Tigo uses a "safety" button (via the on-site communications box or activated online, but the communications box requires AC power to do so). SolarEdge units are programmed to switch into "safety mode" whenever the inverter is shut off. In microinverter-based systems, shutting down the AC disconnect (or PV backfed breaker) automatically shuts down each microinverter and thus each module's AC output.

Forthcoming safety requirements could significantly impact the distributed MPPT market. A potential *National Electrical Code* requirement (slated for 2011) calling for "DC Arc Fault Circuit Protection" devices may be implemented. This protection device could be built into distributed MPPT equipment to limit the potential for arc faults in PV arrays. Placing them at the module level increases the protection for the rest of the PV circuit, as opposed to placing that protection further downstream (for example, at the inverter). In anticipation of this new requirement, a few distributed MPPT equipment manufacturers are already including this feature in their equipment (see table).



Courtesy www.enphaseenergy.com (3)

As the only microinverter currently available for the residential PV market, Enphase has been leading the industry in AC MPPT technology.

Online monitoring is now available as an iPhone app.

Products for MPPT of Individual Modules

DC-to-DC MPPT	Model	Retrofit Option (Existing Inverter)	Series / Parallel	Matching Inverter	Module-Level Monitor	Remote Shut-Down	Arc Fault Protection	Unit Required for Each Module?	Efficiency	Cost***	Warranty (Yrs.)
eIQ www.eiqenergy.com	Parallux	Yes	Parallel	No	Yes	Yes	Yes	No*	97–98%	$99, $139	20
SolarEdge www.solaredge.com	Power Box	No	Series	Yes	Yes	Yes	Yes	Yes	98.5%	Kits $3,597 up, incl. inverter	25
National Semiconductor www.solarmagic.com	Solar Magic	Yes	Series	No	Yes	No	No	No	98.5%	$175 + $79 required diode	20
	SM3320	No**	Series	No	No	Yes	Yes	No	99.5%	$75	25
Tigo Energy www.tigoenergy.com	Maximizer ES	Yes	Series	No	Yes	Yes	Pending	Yes	99.6%	$56	20
	Maximizer EP	No	Parallel	Yes (Kaco)	Yes	Yes	Yes	Yes	97.5%	$79	20
Xandex www.xandex.com	Sun Mizer	Yes	Series	No	No	No	No	No	98.0%	$250	20

Microinverters	Model	Retrofit Option (Existing Inverter)	Series / Parallel	Matching Inverter	Module-Level Monitor	Remote Shut-Down	Arc Fault Protection	Unit Required for Each Module?	Efficiency	Cost***	Warranty (Yrs.)
Enphase www.enphaseenergy.com	Enphase	—	Parallel	N/A	Yes	Yes	No	Yes	95.0%	$230	15

*More than one module can be wired into a single unit; **Module-integrated; ***Communications equipment and online system monitoring access costs not shown

Cons

So, what are the drawbacks? The most obvious is increased up-front cost compared to the traditional centralized inverter approach. But does the increased energy production and access to additional features (monitoring and safety) pencil out with the additional equipment purchase and installation time? It depends on the PV system's specifics: the amount of array shading (the more shading, the more likely increased energy can be harvested with these devices); various orientations/tilt angles; or different models of PV modules within the same system. Chances are, if your system does not fit into these categories, the additional cost of the equipment will not balance out with the increased energy yield. However, the desire to add module-level system monitoring or the safety features included may be enough to tip the scales for some system owners. Several manufacturers are taking steps to integrate their MPPT devices into the modules to decrease overall system cost and installation time. National Semiconductor's SM3320 unit is one example.

Another consideration is that these devices use some energy to perform their functions. The question is, then, does the increased energy harvest exceed the energy lost in the device? If so, by how much? Again, the answer depends on the PV system's specifics, such as the amount of shading and any module mismatch. DC-to-DC converter efficiency ranges from about 97.0% to 99.6%. Parallel configurations are on the low side of that range, due to the significant voltage boosting that they must perform. To fairly compare these systems against microinverter-based ones, you'll also need to account for the centralized inverter's efficiency.

These products are new to the industry—there is not yet a track record. All claim to have performed some field-testing and "accelerated life testing" on their products, but it is difficult to predict if the thermal cycling these units endure will take a toll on their electronics—yet most carry 15- to 25-year warranties.

Comparing Your Options

Currently available, UL-listed DC-to-DC converters and micro-inverters are compared in the table, including the following:

- **Retrofit option**—Can the product be installed on the existing system with an existing inverter? Most of the DC-to-DC converters can be used with an existing system that has a central inverter. Microinverter systems will generally only be installed on new systems, since most folks will not want to get rid of an already purchased and installed central inverter. In either case, make sure your modules' voltage and amperage are compatible with the equipment you are using.

- **Parallel or series configuration**—All microinverter systems will connect to each other in a parallel configuration (voltage stays constant; current is additive).

Xandex's SunMiser units only need to be installed on modules that have shading, reducing up-front costs.

Courtesy www.xandex.com

DC-to-DC converters are designed for either, but not both, parallel or series (voltages are additive; current stays the same).

- **Matching inverter available**—Some DC-to-DC converters can be matched to specific inverters, which are altered and optimized for use with this equipment, further increasing system efficiency. (Currently, SolarEdge PowerBoxes can only be used in systems with a SolarEdge inverter.)

- **Units required**—Is one unit needed per module, or only needed on shaded modules? Can multiple modules connect to one unit? If you do not need to install a unit on every module in the string, you can reduce your up-front cost. However, other benefits, such as tracking MPPT individually for all modules, module monitoring, and array safety features, may not be available.

- **Cost per unit**—If one unit is required for each module, you will need to multiply this times the number of modules in the array, and add any other desired/needed components expenses (such as communications equipment, online monitoring/subscription contracts, etc.) to calculate the full cost. SolarEdge pricing is for kits, which include several power boxes and their inverter.

Out of the Shade

Sage solar advice is to install PV arrays on shade-free, south-facing rooftops. While good counsel, what about sites that have a little shading, multiple module types, or multiple orientations? The boom in residential grid-tied systems is pushing manufacturers to devise solutions, since shading, module variations, and using various roof planes are a reality for many installations. Distributed MPPT products are one solution, yet viability for *your* installation depends on the circumstances.

Another indicator that this technology is on the rise is the many more manufacturers—in addition to those listed here—that are in various stages of developing their own distributed MPPT products, including Enecsys, Exeltech, Greenray, SMA/OKE, Direct Grid, and SolarBridge. In the years to come, it will be interesting to see which products will ultimately be standing out in the sun—or rather, under the shade of the modules.

Access

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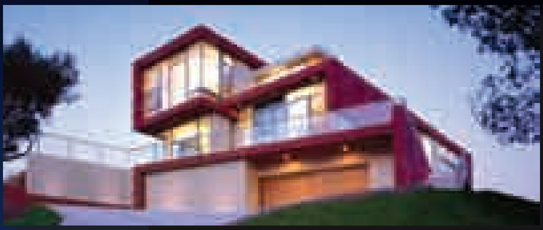


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BACKUP ELECTRIC WATER HEATERS

Ready to retire your old electric tank-style water heater? Here's what to consider before you replace it.

by Chuck Marken

Heating domestic water can consume up to 25% of a home's energy budget, so the choice of heater and energy types is important. Conventional fossil-fuel choices include natural gas, propane, fuel oil, and electricity, although electricity can also be derived from renewable sources, such as large- and small-scale hydro-electric generation, geothermal, wind, solar, and biomass.

While natural gas and propane-fueled heaters tend to be more economical choices at present, that may not always be the case as prices increase. Regardless of the conventional energy source used for water heating, you can use a solar thermal system for preheating. And pairing that with an electric backup heater powered by a grid-tied PV system can offer longer-term savings and sustainability.

Ben Root (2)

Tank-Style or Tankless?

Conventionally fueled water heaters are available as either storage-tank versions or tankless (instantaneous or demand) models. Storage-tank heaters are the standard in the United States, while instantaneous heaters are more common in other countries. To some extent, this is due to the prevalence of hard (mineral-rich) water that can scale the small waterways in an instantaneous water heater.

Compared to fossil-fuel-fired tanks, which have an uninsulated vent pipe exiting the middle of the tank top, electric tanks typically have lower standby losses. (The exception is super-high-efficient, condensing gas-fired water heaters that use PVC pipe for a flue.) Lower standby losses combined with the possibility of RE-generated electricity make electric tanks attractive for use as a backup for solar hot water systems.

Instantaneous heaters are more efficient than storage-tank-style heaters since they have no tank to incur standby losses, but the heaters themselves are usually more expensive than common tank types. Plus, their retrofit can be expensive. For gas units, a retrofit can require adding gas piping and venting; for electric units, household electrical service may have to be upgraded.

Some High-Efficiency* Electric Tank-Style Water Heaters

Manufacturer	Model	Capacity (Gal.)	Warranty (Yrs.)	First-Hour Rating (Gal.)	Energy Factor
Rheem www.rheem.com	Imperial 83XR40-2	40	10	55	0.95
	Imperial 83XR52-2	50	10	67	0.95
A. O. Smith www.hotwater.com	Conservationist	40	10	56	0.95
	Conservationist	50	10	60	0.95
	Conservationist	66	10	72	0.95
	Conservationist	80	10	81	0.95
State Industries www.statewaterheaters.com	Premier (tall models)	40	10	56	0.95
		50	10	60	0.95
		66	10	72	0.95
		80	10	81	0.95
Whirlpool www.whirlpoolwaterheaters.com	Energy Smart EE3J40RD045V	40	12	not listed	0.95
Maytag 866-362-9898 (ext. #2)	Series 12 PC: HRE212 50PC	50	12	61/68	0.95
	Series 12 PC: HRE212 82PC	80	12	86/92	0.95

*Note: Selections based on an EF ≥ 0.95

Electric Water Heating Basics

Electric water heaters use electrical resistance heating. If you run too much electrical current through a wire, it will get hot—glowing hot—just before it melts. The current in all modern home electrical systems is limited by a fuse or circuit breaker to ensure the household wiring doesn't get overheated and melt. Hot wires can cause devastating fires, but the concept is useful for obtaining usable heat.

Elements in heat-producing appliances are usually made from nichrome—an alloy of nickel and chrome with a high resistivity. Nichrome-wire water-heater elements are covered with copper or stainless steel to protect the nichrome, but still allow the heat to be transferred to the water.

Except in the smaller sizes, electrical water heater elements are rated at 4,500 and 5,500 W. The higher wattage and stainless-steel covered elements are associated with more expensive heaters. What does the extra 1,000 W get you? Quicker recovery time. Residential tank-type electric water heaters with storage capacities greater than 20 gallons have a top and bottom element, but the elements are never on at the same time due to thermostatic controls. A 4,500 W element will heat 40 gallons of 60°F groundwater to 120°F in about 80 minutes. A 5,500 W element heater will recover or heat the same amount in about 65 minutes. For an 80-gallon tank, the recovery time would be doubled since it uses elements of the same size. Many larger heaters just use 5,500 W elements (see "Useful Conversions & Calculations" sidebar).

There are a lot of choices in the electric water heater market; volume and efficiency are important variables.

Useful Conversions & Calculations

- 1 Btu is the amount of energy required to raise 1 lb. of water 1°F; a Btu is used to describe the amount of heat energy in fuels
- 1 gal. of water weighs 8.34 lbs.
- 1 kW of electricity equals 3,412 Btu/hr.
- A 4,500 W element produces an equivalent of 15,354 Btu/hr.
- A 5,500 W element produces an equivalent of 18,766 Btu/hr.

Heating a 40 gal. tank with a 4,500 W element:

8.34 lbs. per gal. x 40 gallons x [120°F – 60°F (rise in temperature)] = 20,016 Btu needed

20,016 Btu ÷ 15,354 Btu/hr. (heat produced by a 4,500 W element) = 1.30 hrs.

Heating an 80-gal. tank with a 5,500 W element:

80 gal. x 8.34 lbs. per gallon x 60°F (rise in temperature) = 40,032 Btu needed

40,032 Btu ÷ 18,766 Btu/hr. (heat produced by a 5,500 W element) = 2.13 hrs.

How Much Hot Water Do You Need?

Do you know how much hot water you use each day? If so, you are in a small minority of the U.S. population. The U.S. Department of Energy estimates that the average American uses 15 to 30 gallons of hot water per day. Water heater manufacturers recommend a 40-gallon water heater for households of three or fewer, while 80-gallon tanks are recommended for families of up to five. Residential water heaters are available up to 120 gallons. Although most households can get by with smaller-than-recommended electric tank-style water heaters, some loss of convenience might be encountered because of the additional recovery time.

Most experts agree that the first-hour rate (FHR) is especially important for tank-style water heaters. If hot water is drawn out of the tank faster than the water heater can heat incoming cold water, the water temperature in the tank will start to decrease.

Heat Loss—A Big Deal or Not?

One disadvantage to storage-tank water heaters is heat loss of the tank to the surrounding air. Fossil-fueled tank heaters have additional loss from the central chimney, which cannot be insulated. But how much energy is lost depends mostly on the tank's level of insulation. Most modern tanks, which are insulated with expanded polyurethane foam, have an insulation rating of about R-6 per inch, as opposed to the 1 inch of fiberglass insulation (R-3) used 30 years ago. Many modern water heater tanks also have little flapper valves at their inlets and outlets to slow heat lost through the system piping.

A threaded electric water heater element, covered in stainless steel so it can be immersed in the tank.

Information on tank heat loss is sometimes hard to find, but the calculation is fairly easy if you have a few numbers. You'll need the surface area of the tank, the temperature difference between the tank and the surrounding air, and the R-value of the tank's insulation.

For example, on a recent visit to the Web site of a well-known appliance manufacturer, models of electric water heaters with 1, 2, and 3 inches of non-CFC (chlorofluorocarbon) foam insulation were listed. While the insulation value wasn't given, we'll assume it was R-6 per inch.

The 40-gallon model with 2 inches of insulation had an outside diameter of 20 inches and a height of 48.25 inches. Subtract the insulation thickness (4 inches from each dimension) and we get a tank measuring 16 by 44.25 inches. Since the tank is a cylinder, use the following formula to calculate surface area:

$$\mathbf{A = 2\pi r^2 + 2\pi rh = (2 \times \pi \times 8^2) + (2 \times \pi \times 8 \times 44.25)}$$
$$\mathbf{= 402.12\ in.^2 + 2{,}224.25\ in.^2 = 2{,}626.37\ in.^2 \text{ or } 18.24\ ft.^2}$$

The difference in the tank and air temperature can vary depending on the tank's location and its thermostat set point: If located inside, water heaters typically experience air temperatures between 60°F and 80°F. An electric water heater thermostat can be set from about 110°F to 140°F.

Example: A 40-gallon water heater with 2 inches of foam insulation is located inside, where the temperature averages 70°F. The heater's thermostat is set to 120°F.

First, find the difference in temperature between the heater and room air:

120°F - 70°F = 50°F

The 40-gallon tank's surface area is 18.24 square feet (see above). The insulation is 2 inches of foam with a factor of R-6 per inch, or R-12 total, which translates into 12 hr.·ft^2·°F/Btu.

18.24 ft.^{2} ÷ 12 hr.·ft.^{2}·°F/Btu = 1.52 Btu/hr.·°F x 50°F = 76 Btu/hr. heat loss

High-Efficiency Water Heater Comparison

Type	Energy Savings vs. Min. Standards	Best Climates	Approx. Lifetime (Yrs.)	Major Advantages
Tank	10–20%	Any	11**	Lowest purchase cost
Tankless (gas or electric)	45–60%	Any	20	Unlimited hot water
Heat pump	65%*	Mild to hot	10	Most efficient electric fuel option in certain climates
Solar with electric backup	70–90%	Mild to hot	20	Largest energy savings of RE options

* Compared to electric resistance. **Maintenance (i.e., replacing anode rods regularly) can extend tank life
Source: U.S. Environmental Protection Agency

The same tank with 1 inch of insulation would be:

18.24 ft.2 ÷ 6 hr.·ft.2·°F/Btu x 50°F = 152 Btu/hr. heat loss

The same tank with 3 inches of insulation:

18.24 ft.2 ÷ 18 hr.·ft.2·°F/Btu x 50°F = 51 Btu/hr. heat loss

Assuming an electricity cost of 10 cents per kWh, a tank with 1 inch of foam insulation will have a daily standby loss of a little more than 1 kWh, or 10 cents. The tank insulated with 2 inches of insulation would have a daily loss of about 0.5 kWh, or 5 cents, and the tank insulated with 3 inches of foam would have daily loss of about 0.35 kWh, or 3.5 cents. Annual costs for standby losses would be about $37 for the 1-inch insulated tank, about $19 for the 2-inch insulated tank, and $13 a year for the 3-inch tank.

The cutaway of a modern tank-style water heater reveals a thick layer of foam insulation, an electric heating element, and the cold water fill tube.

Chuck Marken

Water Heater Conservation Measures

Water heater tank losses are proportional to their environment. In cold climates, the best location for a water heater is in a heated space. A water heater in an unheated garage or basement can lose much more heat. In southern locations with mild winters and six months of air-conditioning loads, an inside location is of no value—in these places, summer cooling costs might exceed winter hot water savings.

Water heater blankets, available at most home centers and online, are a great strategy for insulating virtually any tank if you have room to wrap it. Blankets are more valuable on tanks in unheated locations in cold climates and covering indoor tanks in areas with high air-conditioning requirements. Even used on a well-insulated tank, the blanket's low cost will always return the investment over the tank's 20-year life span. (With care and extra white tape, blankets can be reused on a similar-sized replacement heater.)

Wraps that will cover a 60-gallon tank with an extra insulation value of R-7 to R-10 are available for less than $20. Adding that much foam at the factory could cost more than $100. If you're buying a new tank, a blanket can save you money immediately—the price difference between a tank with 1 inch of foam and 2 inches is always more than the cost of a wrap.

You can easily see where the $20 blanket with more insulation value than an inch of foam is a good deal. However, with insulation values of R-3 per inch—compared to R-6 per inch for foam, blankets have space limitations—you'll only be able to wrap so much around the tank depending on the amount of room between the tank and its surroundings.

Solar Water Heating

The best option for the planet—and maybe your pocketbook

Electricity is often a more expensive choice in places where natural gas is available. Whenever gasoline is less than about $3.50 a gallon, propane and fuel oil are normally less expensive, too. This varies across North America but it is the rule rather than the exception.

With today's increasing electricity rates, households with electric water heaters can make a stronger economic case for solar water heating systems—although pairing a solar preheating system with a gas-fired system can also offer financial savings.

Solar water heaters are available in five different configurations (see Access). Very simple batch-type water heaters and thermosyphon systems (integrated collector and storage systems) are very effective in mild climates such as the southern tier of states and Mexico. Simple direct forced-circulation systems are popular in Hawaii and other climates where freezing isn't an issue. In most of the United States and all of Canada, two types of freeze-protected systems are used: closed-loop antifreeze and drainback. Drainback systems are favored by installers in mild to moderate climates, while antifreeze systems are popular for colder climates.

The return on investment (ROI) of a solar water heater depends upon the solar resource, local incentives, and to a lesser extent, the climate. Solar water heaters work best in areas with mild climates and lots of sunshine. They will work in cold, cloudy climates but the ROI is not as attractive. Many states and utilities have instituted incentive programs in addition to the 30% federal tax credit. For most locations in the United States, any combination of incentives that total 50% to 60% of system costs will cut the payback period of a solar water heater to less than 10 years.

If a water heater has a expected life of 20 years, the cost differences of our simple calculations give us a little guidance. Assuming foam insulation with an R-6 per inch and a 40-gallon tank, and the cost of electricity at 10 cents per kWh, the standby loss costs can be estimated for a period of 20 years and will depend on the insulation thickness (see "Standby Loss Costs Over 20 Years" table).

This is a simplified way of calculating the heat loss, but it has some merit for calculating the value of insulation. It can also give some guidance when considering a tankless water heater retrofit. Heat loss is a moving target, since tank temperature, air temperature, and groundwater temperatures change over time. More heat is lost out of the top of the tank than the bottom due to stratification. Higher electricity rates will increase the standby energy savings of a tank with more insulation. And, keep in mind that a larger tank will have more standby loss because the surface area is greater.

Standby Loss Costs Over 20 Years

Insulation (In.)	Standby Loss Cost	Difference
1	$740	–
2	380	$360
3	260	120

A 40-gallon electric water heater with 2 inches of insulation will pay for itself in life-cycle costs if its initial cost is less than $360 more than a tank with 1 inch of insulation (at 10¢ per kWh). Increasing to 3 inches of insulation is not as clear as a money-saver, but it will surely save more energy. As with home insulation, there is a point of diminishing economic return with added tank insulation—2 inches of foam may be close to that line.

Both electric-resistance storage and tankless water heaters present limited individual energy savings potential and are rated by energy factor (EF)—a measurement of water-heater energy efficiency. According to the DOE, the perfect electric-resistance water heater could not exceed an EF of 1.0 due to this technology's physical limitations. The highest-efficiency, electric tank-style heaters achieve a 0.95 EF and the best electric-resistance tankless water heaters achieve a 0.99 EF.

Access

Solar thermal editor **Chuck Marken** (chuck.marken@homepower.com) is a licensed plumber, electrician, and heating and air-conditioning contractor in New Mexico, installing and servicing solar thermal systems since 1979. He is an instructor for Solar Energy International and the Department of Energy's Solar America Cities Program, and teaches solar workshops throughout the United States.

Further Reading:

"Solar Hot Water: A Primer," by Ken Olson, *HP84*

"Solar Hot Water Simplified," by John Patterson, *HP107*


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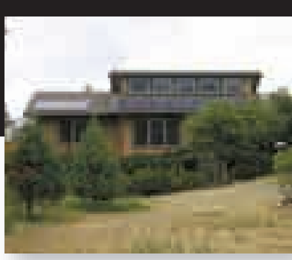
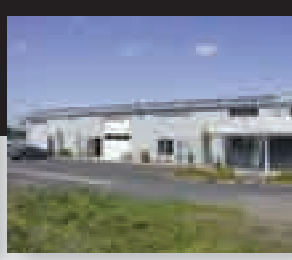
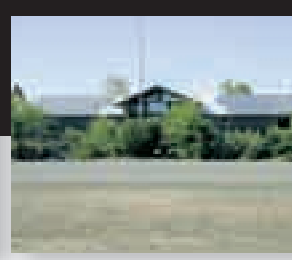
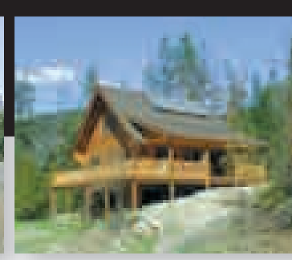
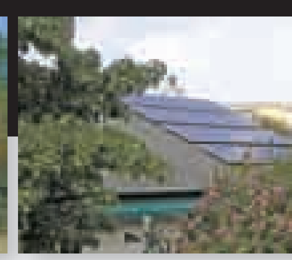

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Start four of the supplied ¼-20 bolts into the pemnuts to mount the MMP enclosure. Four mounting keyholes allow you to simply place the enclosure over the bolts and tighten them without having to support the enclosure during installation.

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MODERN PV ROOF MOUNTING
Faster & Less Expensive

Courtesy www.quickmountpv.com

by Rebekah Hren

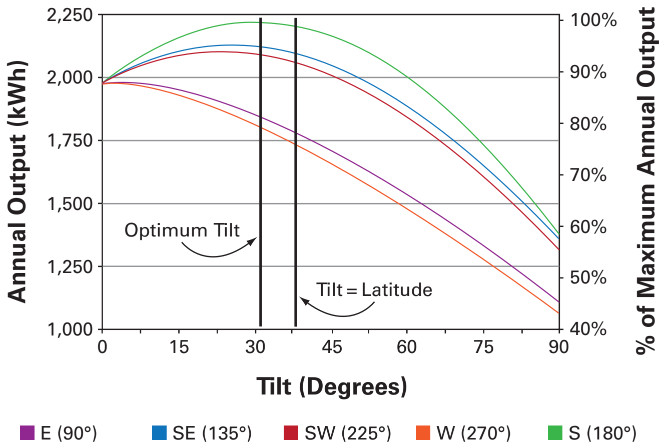
If, while traveling, you keep your eyes on roofs looking for solar arrays, there's a good chance you've been bitten by the solar bug. The low-pitched roof on a ranch house sitting out in the wide-open sun—hey, that's a good one for solar! How about that 1920s Craftsman bungalow, or the new mini-mansion with the steep, slate-covered trapezoidal roof? What are the PV possibilities for roofs like these? And what innovations are making roof-mounted systems easier to install, more durable, and less expensive?

Any PV system needs sufficient sun access: a steady, unshaded six hours a day (generally, from 9 a.m. to 3 p.m.) is recommended. Several other factors come into play for roof-mounted systems: the roof's pitch and azimuth, plus the roofing material itself. Standing seam, face-fastened, corrugated or shingled metal, asphalt (a.k.a. composition or "comp") or wood shingles, slate, concrete, clay or spanish tile—whatever the surface, a manufactured mounting solution is available, although that doesn't mean every installation will be straightforward or simple.

For nearly a decade, the most common pitched-roof PV racking systems have been based on "top-down mounting." This method uses compression clips or rails to secure the module frames, rather than bolting through the holes in the back of the module frame. Top-down mounting incorporates roof brackets, rails, and module clips of various designs. The metal frames for most modules are made of anodized aluminum of varying heights and gauge. Accordingly, most racking systems can accommodate hundreds of different makes and models of modules, with only a change of clip height, color, or style.

The goals of the PV industry include reducing system cost, improving efficiency, and increasing safety and longevity. Much research and development has focused on modules and inverters—but there has been only incremental change in racking methods. Top-down racking systems incorporate costly raw materials, including metal attachment brackets and standoffs, rails, clips, and hardware. Those parts and pieces can be time-consuming

PV Output at Various Angles & Orientation*



*For a 2 kW array in Pittsburgh, PA

Pitch & Azimuth

The pitch (or slope) of a roof matters—first to the installer trying to mount modules, and second to the system's energy production. The azimuth, or compass direction the roof faces, factors in as well. For most sites, the more closely a roof's azimuth aligns with true south, and the closer the pitch is to the site's latitude, the higher annual energy production will be.

When estimating the solar potential of a roof, slope and azimuth are used along with historical weather data and shading percentage to figure out how close to optimal the site is. The National Renewable Energy Laboratory's PVWatts calculator (www.nrel.gov/rredc/pvwatts) is a popular and accurate tool for estimating production. When user error is avoided with correct data input, the estimates prove to be high-quality when checked against real-world figures.

The graph (above) shows the production and percent of maximum for a 2 kW array at different pitches and azimuths, including the optimal tilt and true south orientation, in Pittsburgh, Pennsylvania.

While a general rule is that tilting equal to latitude maximizes annual production in fixed grid-tied systems, there are many locations where the maximum occurs at a tilt angle lower than latitude. For example, the latitude of Pittsburgh is 40.5°, but highest annual production is at a tilt closer to 30°. Local climates can affect the general rule—in Pittsburgh, short winter days can be much cloudier than long summer days, so maximum annual output occurs at a lower tilt that is more perpendicular to the summer sun, high in the sky. Even at a 20° pitch, with other variables held constant, a system will still produce 98% of that highest production value.

Local weather conditions also affect the ideal orientation for an array. For example, coastal communities may have morning fog, in which case orienting the array toward the west may result in better production.

to install, and grounding the racking system takes extra care and additional materials.

Racking generally accounts for 5% to 10% of an installed system's materials cost and between 20% and 40% of the labor cost. If installed system cost continues dropping, due to module per watt price decreases, but racking material and labor costs stay the same, those percentages will creep up. Thus, racking has found itself squarely in the sights of innovation.

Reducing Materials

Pitched-roof racking needs to be lightweight, yet strong enough to withstand at least 25 years on a roof that's subject to intense physical stresses (including wind, snow, UV exposure, and extreme thermal cycling). Racking systems have traditionally used substantial quantities of expensive and high-embedded-energy materials—mostly anodized aluminum and stainless steel for strength and longevity.

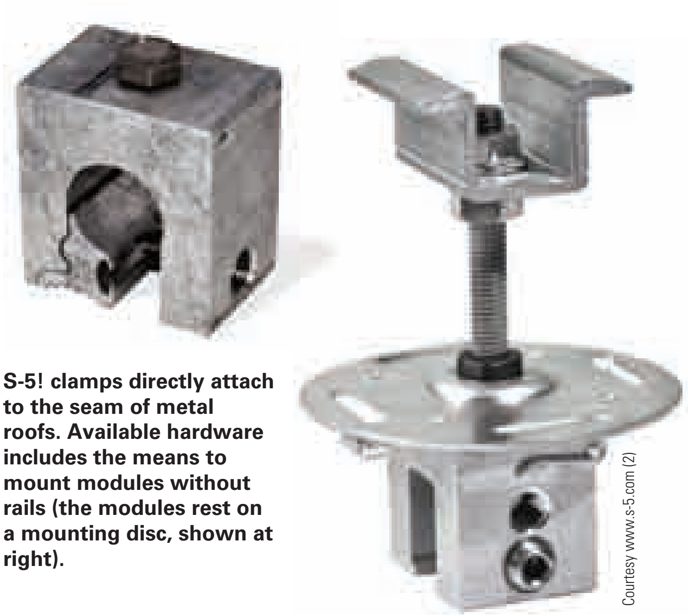
To reduce costs and "energy payback," racking manufacturers are engineering solutions that use fewer raw materials, while maintaining strength and integrity. One such solution entails eliminating the rails that traditionally attach to roof-mounting brackets and run beneath or between modules. Both Zep Solar and Akeena Solar have introduced PV array systems featuring a slot in the module frame that enables rapid installation and grounding—without rails. Zep-compatible module frame slots couple directly to adjacent modules and to roof-mounting attachments (customized and flashed for a variety of roofing surfaces). Andalay's slot attaches to roof-mounting brackets, but doesn't couple to modules. Instead, a splice rod is inserted through holes in the frame.

Zep Solar uses Canadian Solar modules that are factory-modified with a mounting groove. Akeena's Andalay product uses modified SunTech modules, which can even be purchased with Enphase microinverters pre-installed to save further installation time. (Note: If you're looking for these

Zep Solar's racking system uses special grooves in the modules, eliminating the need for rails.

Courtesy www.zepsolar.com

Akeena's Andalay PV system uses the module frame, rather than the rails, as the mounting bracket attachment point.



S-5! clamps directly attach to the seam of metal roofs. Available hardware includes the means to mount modules without rails (the modules rest on a mounting disc, shown at right).

products, Andalay is sold directly to dealers/installers, while Zep Solar's systems will be available through distributors like groSolar.)

Eliminating rails could be a giant leap forward, saving raw materials and installation time, and making lighter-weight systems. Neither system has accumulated lengthy test time in the field, so, as with any new product, more data will accumulate as installs increase.

Another product that can eliminate the need for rails is the S-5! nonpenetrating clamp for standing-seam metal roofs. Installers can purchase S-5! PV kits which include module clips and hardware that attach directly to the roof clamp, or they can purchase the S-5! clamp and separately sourced hardware and rails, which can add flexibility to the installation. S-5! clamps attach with set screws and are available for the differing seam styles found on metal roofs. (The S-5! PV kit clamps come in two different heights to match module frame heights.) Set-screw seam clamps like the S-5! are unique since they are the only nonpenetrating attachment method for PVs on pitched standing-seam metal roofs.

Another product line aimed at reducing raw materials is Unirac's Clicksys system. Based on an I-beam rail that snaps into a mounting attachment, Clicksys reduces the hardware and time required to bolt rails to mounting feet. Unirac says that Clicksys uses 10% to 50% less material than typical extrusion rail systems, as the I-beam rail has a higher strength-to-weight ratio. While faster to install, the spans between roof-mounting attachments are generally shorter for Clicksys, which means more roof penetrations might be necessary. The Clicksys mounting bracket can be bolted on top of primary flashed brackets, available for each type of roof surface.

Eliminating Roof Leaks

The *International Building Code* requires flashing every roof penetration, a shift away from relying solely on sealants as with the old L-feet method. Flashing is a thin metal or rubber sheet overlapped by the roofing material so that all penetrations are protected from water running down the roof. Flashing can be separate from the mounting attachment, like Oatey flashing, which slides under shingles and wraps

Oatey makes flashings for a variety of roof penetrations, including stand-off posts for PV racks.

web extra

For more information on roof-mounted systems and mounting details, see "Rack & Stack: PV Array Mounting Options" in *HP124* and "Pitched Roof Mounting" in *HP130* at **www.homepower.com/webextras**.

tightly around a mounting post, or some manufacturers integrate the flashing into the post itself. If a new roof is being installed prior to a PV installation, then flashing for mounting attachments should be installed by the roofers so the flashing installation is covered by the roofing warranty.

Quick Mount PV, a manufacturer of flashing-integrated mounts, created the "Wheel of Accountability" (available on its Web site; see Access), which summarizes the different authorities that have rules, regulations, and guidelines pertaining to roof penetrations. If planning an installation, perusing the Wheel can clarify where an installer should look for more information on roof mount regulations.

Every major racking manufacturer offers flashed mounting solutions for installers to use, rather than just relying on sealant. Flashing-integrated products include Quick Mount PV, Thompson Technology Industries' Flat Jack, and EcoFasten Solar's Quik-Foot and Green-Fasten.

Courtesy www.quickmountpv.com

Quick Mount makes a clean, under-array rack system for concrete tile roofs.

Rooftop PV innovation doesn't stop with the mounts. Roof-integrated boxes like the SolaDeck enclosure and combiner box are providing flashed solutions for the entry of PV conductors to the building interior. SolaDeck meets UL 1741 requirements for PV combiner boxes, as mandated by the *2008 National Electrical Code*. They are low-profile for sleek aesthetics (and can be mounted under an array), while providing multiple functions—transition to interior conduit, flashed penetration, and even PV string combining. But the SolaDeck can be hard to access for troubleshooting, especially if positioned under the array.

Less Materials, Fewer Tools

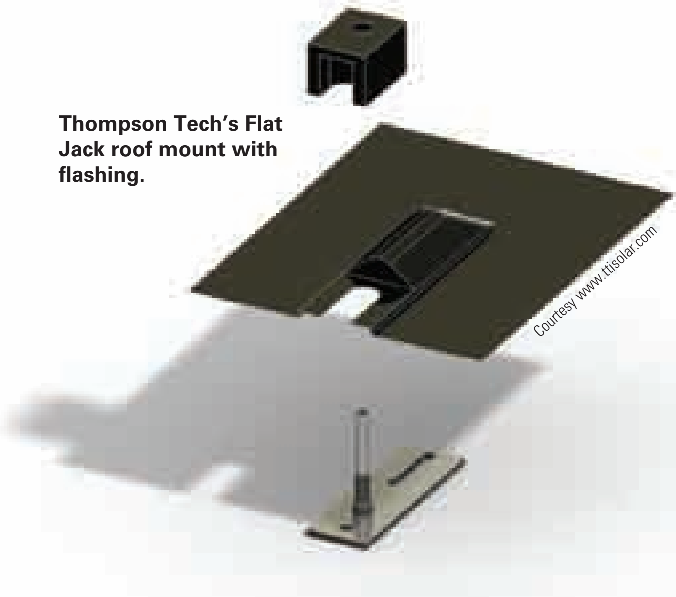
Older, tried-and-tested racking systems often use both 1/4- and 3/8-inch hardware, in addition to the stainless steel lag bolts for attaching brackets into rafters. This means multiple tools and multiple nuts and bolts must be managed on the roof.

Newer systems such as AEE Solar's SnapNrack and Unirac's Clicksys use only one standard-size hardware besides the lag bolt—one wrench fits every bolt in the system. SnapNrack uses snap-in channel nuts, which eliminate holding, sliding, or dropping bolts, and also allows easy adjustments to keep arrays square and in the same plane regardless of roof irregularities. And to further help installers to fast-track their installations, mount manufacturers provide online code-compliant installation guides, engineering documentation, and training videos.

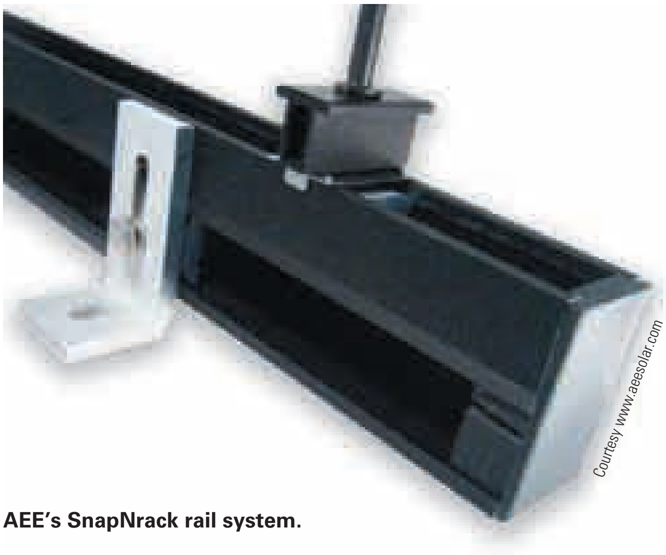
Making installations easier is important even for less-common roofing materials that often prove difficult to conquer with typical PV racking. Tiles, whether slate or concrete, metal

This cutaway of EcoFasten's roof mount shows the rubber seal that keeps leakage out of the penetration.

Courtesy www.ecofastensolar.com



Thompson Tech's Flat Jack roof mount with flashing.



AEE's SnapNrack rail system.

shingles, and face-fastened metal roof (also known as barn tin or 5V tin) all present challenges. Fortunately, attachment methods for each type of roofing material are available to ease the installation. S-5!'s new Versabracket for face-fastened metal roofs and CorruBracket for corrugated metal roofs are versatile solutions for these tricky roof types. While neither uses integrated flashing, there is no easy way to retrofit flashing into these types of metal roofs. DPW Solar's EZ-Foot, which can be screwed down to the roof sheathing rather than having to be lagged into a rafter, is another practical solution for face-fastened metal roofs. Tile roof installations can use Conergy's SunTop racking system with tile roof hooks, and Quickmount PV mounts, which replace entire tiles.

Module Grounding

The *NEC* requires that any exposed metal surface be grounded if it could become energized. This includes PV modules' metal frames, which could become energized in various ways, including ground faults and wire insulation failure.

Traditional module grounding has relied on bare copper equipment-grounding conductors attached to tin-plated copper lay-in lugs (like the Ilsco GBL4 DBT and Burndy CL50-DB-T) at the modules' grounding points. This procedure is time-consuming, and the materials are fairly expensive. Wiley Electronics, the manufacturer of WEEB clips, has been at the forefront of new module grounding technologies. A WEEB is a stainless steel square that fits around a module racking

Removing roofing nails to slide an AEE Solar flashing over the foot and its penetration.

SolaDeck makes a combiner box with integrated flashing.

Courtesy www.lumossolar.com

Lumos Solar's Project X frameless module and racking system.

bolt between the module and rail and "bites" through the anodized non-conductive coating on the module and rail as the bolt is tightened. However, this method is not accepted by all module manufacturers or inspectors—so you'll need to check with both the module manufacturer and the inspection authority before using them.

The Zep Solar and Akeena Andalay systems are also pushing innovation in module grounding. Both systems have integrated grounding, meaning modules are connected together mechanically and electrically as they are installed on a roof, so no additional grounding hardware is needed for the module frames. The Andalay system uses a threaded stainless steel rod to tighten modules together and create a continuous equipment ground. Zep Solar's design relies on an "interlock" between modules that provides structural integrity and equipment grounding simultaneously.

Improved Wire Management

Mismanaged PV wiring can allow animals and weather to damage wires, conduit, and connectors, so safer and easier wire management is a target of innovation. Module cables and series string home runs should be adequately secured. Left free, they have the possibility of scraping across the roof surface, which could abrade the cable's insulation and pose a shock hazard.

Wiley Electronics' durable, stainless steel Acme cable clips grip one or two module cables and the module frame,

Courtesy www.s-5.com

S-5! CorruBracket provides a solution for mounting on corrugated metal roofs.

Courtesy www.conergy.us

Conergy's Sun Top racking system's tile roof hook.

Courtesy www.we-llc.com

WEEB clips provide an easy way of electrically connecting modules to racks for good grounding.

more easily securing module interconnection wires to module frames. But that still often leaves the series home run wires to manage. It's doubtful that nylon cable ties will last 25 years in the extreme roof environment. Some manufacturers are adding channels to the rack where wires can be tucked neatly inside, including AEE's SnapNrack and NGE's Zilla Rac system. This is not conduit or raceway, and is not listed as such, but should help to keep the squirrels at bay.

Frameless Module Installation

Frameless thin-film modules are starting to hit the marketplace, especially in popular system leasing programs. Pitched-roof racking for frameless thin-film modules require softer plastic- or rubber-gasketed end- and mid-clips that replace the all-metal clips used for framed modules. Both Schletter and HatiCon (established in Europe, though new to the U.S. market) make clips for thin-film modules. Also keep an eye out for monocrystalline frameless modules entering the market soon. Lumos, out of Boulder, Colorado,

Courtesy Rebekah Hren

SnapNrack rails provide a convenient tray for PV wire runs (shown here with one of a series of Enphase inverters).

is in final UL testing for a frameless module that bolts through the module and directly to the rail, without mid- or end-clips. Because it has no metal frame, it won't require module grounding. The Lumos module will also include a wire raceway with integrated rodent protection to reduce conductor damage.

Access

Rebekah Hren (rebekah.hren@o2energies.com) is a licensed electrical contractor and NABCEP-certified PV installer in Durham, North Carolina, where she is implementing large ground-mount solar arrays with O2 Energies. Rebekah co-authored a book on residential energy-efficiency retrofits: *The Carbon-Free Home.* Her new book, *A Solar Buyer's Guide for Home & Office*, a solar-electric and solar thermal buyer's guide, will be published this fall.

Racking Manufacturers:

AEE Solar • www.aeesolar.com
Conergy • www.conergy.us
Direct Power Solar • www.power-fab.com
EcoFasten Solar • www.ecofastensolar.com
HatiCon Solar • www.haticonsolar.com
IronRidge • www.ironridge.com
Jac Rack • www.jac-rack.com
Next Generation Energy • www.zillarac.com
Professional Solar Products • www.prosolar.com
Quick Mount PV • www.quickmountpv.com
S-5! • www.s-5.com
Schletter Inc. • www.schletter-inc.us
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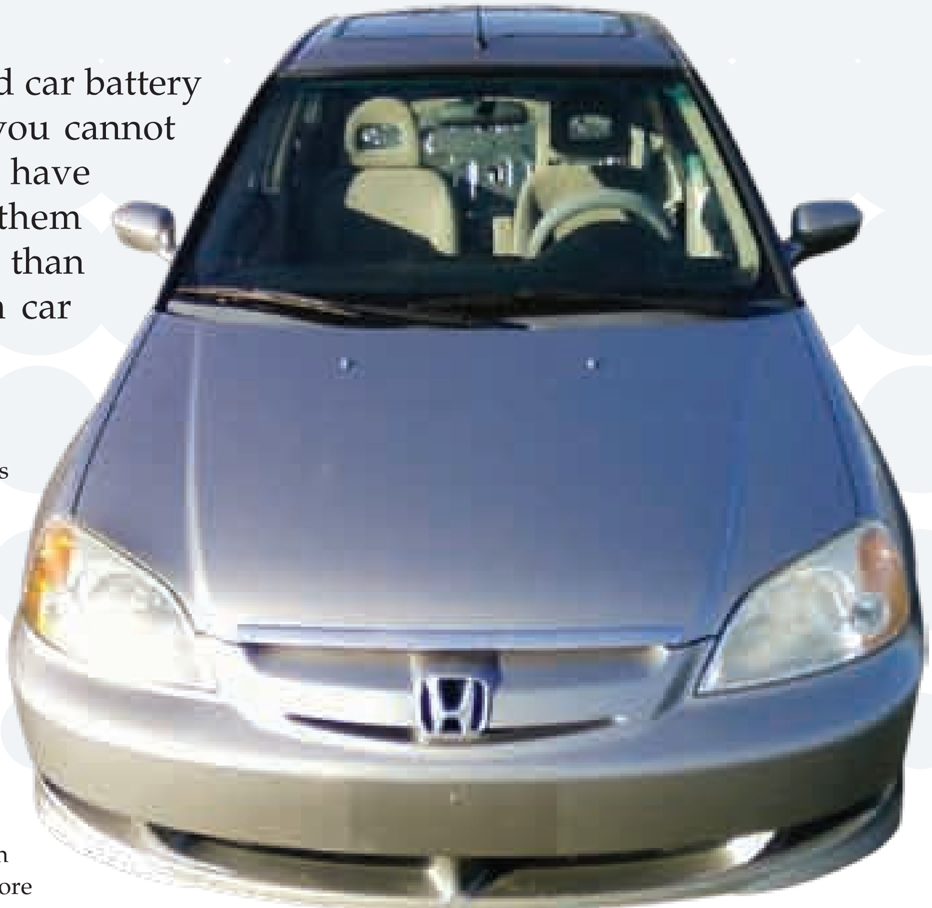
REBUILDING a Hybrid Vehicle Battery Pack

Story and photos by Michael P. Lamb

Reconditioning NiMh hybrid car battery packs is time-consuming—you cannot rush it! However, if you have patience, reconditioning them yourself can save you more than 90% of the cost of having a car dealer do the job.



Last fall, I bought my friend's dysfunctional 2003 Civic Hybrid. It was not something I needed, but it did have only 110,000 miles on the odometer and some nice custom features—and it was cheap! Plus, it had been well-maintained: All the dealer checkups and service had been properly performed.

But besides the car's computer spewing some error codes, it also had performance issues suggesting expensive battery problems. The car was very sluggish and its mpg had dropped off—from more than 50 mpg to 35 to 40 mpg. It stalled easily; the auto-stop function—which turns off the IC engine when the car comes to a full stop—did not work; and, of course, the "check engine" and integrated motor assist (IMA) warning lights wouldn't shut off.

The Honda dealership wanted $3,200 to replace the battery pack with a factory-refurbished one (new cells are not available for a Civic Hybrid of that vintage). Replacement battery packs are made from dead packs dealers return to Honda, which recovers the remaining good subpacks for reuse. These refurbished packs include a one-year factory warranty. There is at least one third-party that claims to do the same thing for $1,250, but you have to sell him your old battery pack first, which he uses for salvageable parts. The few online bloggings from DIYers who tried reconditioning their own packs were not very insightful. However, by doing a lot of "reading between the lines," I felt I learned enough to try my hand at refurbishing.

The root of the batteries' underperformance had to do with the nickel metal hydride (NiMH) cells getting warm from discharging and charging. After thousands of cycles, the fine nickel powder inside starts to form larger nickel crystals, which eventually impede the electrons from flowing. If the crystals get big enough, they can puncture the separators between the positive and negative sides of the cell, shorting the cell. Reconditioning helps break up these crystals. Although it won't make the cell like new, it'll result in a better-functioning cell.

Preliminary Precautions

All you need to recondition IMA battery packs are a few basic tools: a good digital multimeter; the right charger/reconditioning machine (there are several to choose from online); a #30 Torx driver; standard hand tools; and, most importantly, the will and time to do the work right. Because this project can take several weeks of charging, you may need a second car to drive until the project is completed.

ACCESSING THE BATTERIES

Left: Removing the rear seat. There are three 10 mm bolts, one on either side of the seat (as shown) and one near the middle of the seat.

Right: Removing the seat reveals the main battery box cover.

Hybrid car blogs published plenty of warnings about getting electrocuted from the batteries. Since this was new territory for me, I took this advice seriously—but there is only one place on a battery pack where any real hazard exists: from voltage across the full pack, which can be up to 180 VDC.

That single location is easily found with a multimeter, and once you turn off the IMA pack's built-in circuit breaker and start unbolting the individual subpacks, the risk drops significantly since the sticks are only about 8 V each. Honda designed the battery pack in an almost idiot-proof way. The terminal bolts and other fasteners are arranged so that it is easy to avoid touching two ends of any higher-voltage terminals at the same time. Common sense coupled with basic mechanical skills meet most everything else you come across during this task. But working carelessly can still hurt, as well as cause you expensive additional repairs.

Dissassembling the System

Start by parking the car in a place it can stay for a month or two. Finding that you need to move the car after you've removed the battery pack is a real bummer, since the car will not move under its own power without a working battery pack.

Next, remove the rear seat cushions (three 10 mm bolts and some plastic clips). Then take off the small cover over the battery box's circuit breaker (two bolts, #30 Torx), remove its red plastic safety cover and turn off the circuit breaker. The 180 VDC electrical hazard is now gone—the breaker separates about 40% of the sticks from the rest of the pack. Nonetheless, be careful as you work. To get the main cover off, you will need to break off the little black plastic safety snap/pin to the right of the circuit breaker with a large, flat screwdriver.

Remove the metal main battery box cover (six bolts, #30 Torx) and slide the entire cover up an inch or two to release the two metal fingers on the extreme right and left of the cover. You may need to have someone hold the seatbelts to one side to do this.

Once the cover is off, you will find a bewildering array of wiring and connectors. If you disconnect the 12 V battery (yes, there is a standard car battery, too) in the engine compartment, even that small hazard is eliminated. To do this, disconnect the cable at the negative battery post and insulate the end completely with electrical tape or a similar insulating material. This is safer than disconnecting the positive side and less likely to create a short to the chassis. In any case, continue to be careful not to bang up anything since replacing broken terminals or repairing cut wiring is a major and unnecessary chore.

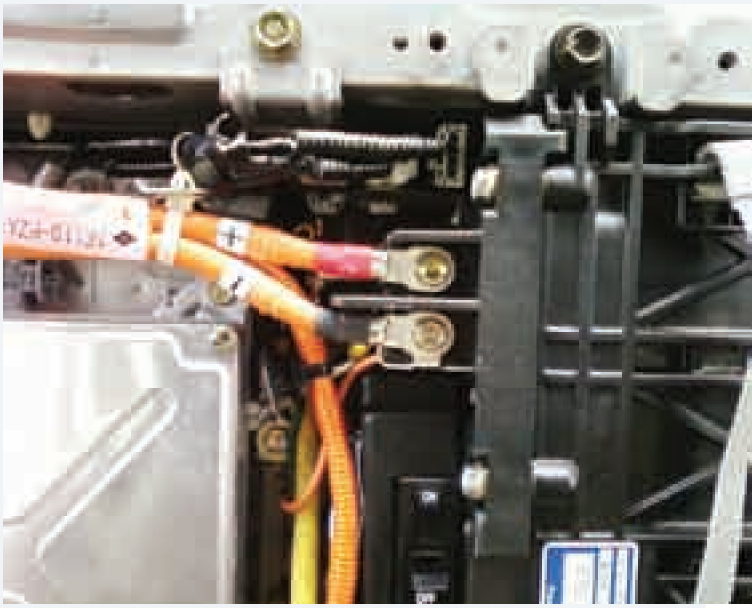
Inside the battery box, remove the three 10 mm bolts that hold the two main IMA power wires and ground wire for the battery pack. Unplug the five sensor connectors from the pack. Then remove the four 12 mm bolts that hold the battery pack in the metal box (two on the top of the pack and two on the bottom). Gently bend any wires out of the way and lift out the battery pack. It weighs about 50 pounds and you will be stooped over in an awkward position, so protect your back and consider having a friend help with the lift.

LOCATING THE MAIN CIRCUIT BREAKER

Remove the main circuit breaker cover. Make sure it's in the "off" position and remove the red plastic safety cover, breaking off the plastic pin.

GETTING TO THE BATTERIES

In the car, with the battery box cover and seats out. Note the yellow wire for the external charging port.



ACCESSING THE SENSOR WIRES

The main power connection: The three sensor connectors sit above the positive and negative wires.

Use the existing carry straps to lift it, being careful not to get tangled up with any wires. Take a few photos as you go along so you remember where everything goes in a month (or two) after completion.

Preparing for Reconditioning

I set up my work area in the living room, since it is climate-controlled and well-illuminated. Find an organizable work area, because there will be no less than 90 assorted bolts and screws holding the pack together. As you take apart the pack to access the subpack sticks inside, you'll need to keep a close count of all the fasteners—use a spill-proof container!

You cannot disassemble the sticks—they are welded together in groups of six cells and tightly wrapped in yellow plastic. These yellow sticks are what you will be "reconditioning" with your new charger/reconditioner machine. Remove each stick from the plastic holding frame to allow for easy judging of how warm each cell gets as reconditioning proceeds. Each stick has a "square" end and a "hex" end. The *positive* side is the *square*—mark it as such to avoid confusion. If you do connect the charger in the wrong polarity, it is smart enough to scream at you and display "connection reversed" before any damage can be done to the cells.

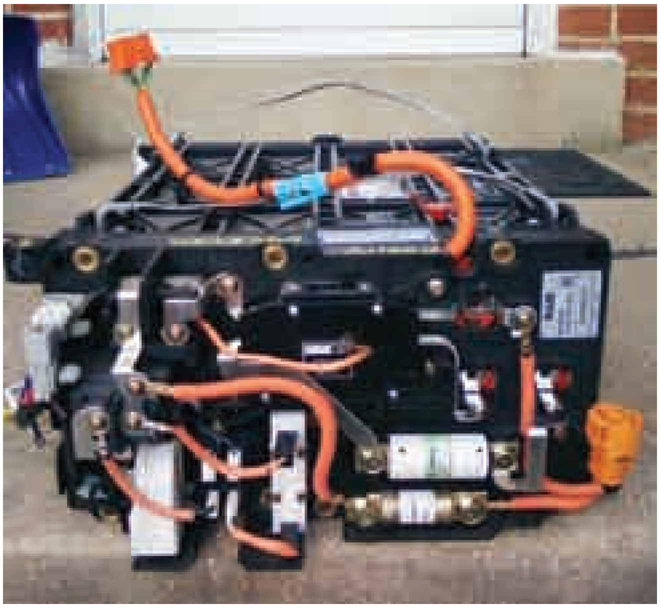
Be careful of the small sensor wires attached to three of the sticks—they pull apart easily and are a major pain to put back

FINDING THE FOURTH SENSOR

The fourth sensor connector sits below the main positive and negative wires.

THE BATTERY PACK, REMOVED

The circuit breaker fuse and the wiring side of the pack.



THE REMOVED CIRCUIT BREAKER ASSEMBLY

Take care to keep track of the twenty 10 mm bolts and temperature sensor wire routing; note the four round metal spacers—where the circuit breaker makes its electrical connections to the sticks.

NiMh Reconditioning History & Results

Original Stick	Initial Voltage	Initial Fill (mAh)	1st Discharge (mAh)	1st Charge (mAh)	2nd Discharge (mAh)	2nd Charge (mAh)	3rd Discharge (mAh)	3rd Charge (mAh)
1	8.2	1,520	2,300	6,010	4,500	6,400	5,700	6,400
2	8.2	1,230	2,000	5,800	4,800	6,325	5,752	6,385
3	8.2	1,236	1,200	5,500	—	—	—	—
4	8.2	1,260	2,000	6,400	5,099	6,355	6,000	6,400
5	8.2	1,252	2,500	6,400	5,125	6,400	5,900	6,388
6	8.2	1,245	750	1,100	—	—	—	—
7	8.2	1,236	2,270	6,200	5,400	6,400	5,955	6,400
8	8.2	1,254	1,969	5,920	5,820	6,399	6,100	6,402
9	8.2	1,258	1,800	4,500	—	—	—	—
10	8.2	1,259	4,500	6,250	—	—	—	—
11	8.2	1,247	2,000	6,255	4,500	6,400	5,987	6,400
12	8.2	1,250	1,620	6,300	4,900	6,389	5,700	6,398
13	8.2	1,220	2,100	5,866	4,800	6,385	5,865	6,400
14	8.2	1,247	750	—	—	—	—	—
15	8.2	1,248	2,200	5,985	5,200	6,399	5,899	6,394
16	8.2	1,236	1,300	—	—	—	—	—
17	8.2	1,257	2,200	6,345	5,700	6,345	5,784	6,400
18	8.2	1,245	3,800	6,400	5,750	6,387	5,762	6,400
19	8.2	1,258	2,050	6,300	5,620	6,344	5,845	6,325
20	8.2	1,205	2,800	6,400	5,312	6,200	5,794	6,385
Replacement Sticks								
1	3.4	6,255	4,500	6,400	5,785	6,400	5,700	6,402
2	3.4	6,200	4,852	6,400	5,799	6,400	5,788	6,400
3	3.4	6,300	4,572	6,399	5,800	6,452	6,100	6,399
4	3.4	6,400	4,620	6,400	6,000	6,420	6,200	6,413
5	3.4	6,355	4,500	6,402	6,100	6,412	6,199	6,400
6	3.4	6,385	4,585	6,405	6,125	6,399	5,755	6,400

■ = Bad battery stick

REMOVING STICKS FROM THEIR HOUSING

Left: The orange bus bar and some of the sticks are removed.

Above: Each stick is fully charged before starting the discharge/charge reconditioning cycles.

again. These three sticks can only be removed from the frame by firmly pushing them from right to left (looking at the pack as it would be in the car). The sensor wires are not very long, so carefully bend them so the sticks they are attached to are not pulling on them. Remember (and take photos of) how the wires are routed around the pack and where their little holders snap together. They will only fit in one way without making trouble for you when reassembly starts.

Reconditioning the Sticks

Although NiMh cells were once thought to be "memory-proof," all nickel-based batteries develop memory problems; NiMhs are just much more resistant to the problem than NiCd cells.

Deep cycling has always been the method of minimizing, and somewhat repairing, memory issues. This is what your charger/reconditioner does, in a very sophisticated way. Its computer brain monitors the cycling cells to optimize breaking up the microscopic nickel "crystals" that form as a cell ages with use. The reconditioning is not perfect and will never make the cell factory-fresh again, but it does go far in making the cell work as well as it can.

Follow the charger manufacturer's instructions for setting up your reconditioner for NiMh cells. Be sure you understand the instructions. I used an iMax B6 ($55) and the instructions had to have been written by someone whose English was not great—it was difficult to understand at first.

Do not despair if the instructions are too difficult to decipher. The default settings for each type of battery (which are already programmed into the charger) seem to work well enough. But I changed the minimum cell state on mine to 0.8 V per cell, just to get a little deeper discharge and, hopefully, a more functional battery in the end. Do not discharge them too far, which can cause cell polarity reversal, which means you end up with a dead stick!

Number the sticks with a permanent black marker to avoid mixing them up. Have a pad of paper and pen handy to record the values the screen displays at the end of each programmed cycle to track how each stick performed. Believe me, after a month or more of this, it is a hopeless task remembering it all.

Fully charge each stick before starting the discharge/charge reconditioning cycles. But before the lengthy cycling process starts, set the machine for a minimum of three discharge-charge cycles. My iMax can do up to five cycles automatically, but you don't really need to spend that much time on each stick to sort the good from the bad. With the good sticks, more than three cycles does not necessarily make the stick perform significantly better. If a stick is somewhere "between" good and bad, then the cycling process often straightens it out nicely.

With the iMax B6, each cycle takes at least 10 hours to complete. Multiply that by 20 sticks and you can quickly see that reconditioning the entire pack will take 25 days of round-the-clock reconditioning. Try to time your "starts and stops" so that the charger alarm doesn't wake you up in the middle of the night, though the alarm can be turned off.

Junkyard Battery Packs

Some disreputable car dealers install junkyard packs as-is. I suggest not succumbing to the temptation of simply replacing a malfunctioning pack with an untested junkyard one. Even though the junkyard pack I bought was only one year old when its car was wrecked and had sat on a warehouse shelf since 2005, it still had two malfunctioning sticks. Spend the time, and do the testing diligently!

CHARGING A STICK

A stick connected to the charger to be reconditioned.

FINISHED STICKS

A pile of finished sticks with final Ah ratings written on each. Note the small metal thermal sensor tabs on each stick.

The iMax B6 is made for small, radio-controlled batteries, and with light loading to keep the cells from getting too hot, the IMA conditioning process is lengthy. But it does get the job done with IMA sticks too, and it is less expensive than similar devices. Other reconditioners use much higher discharge rates and cycle faster. However, the additional heat may also cause otherwise-OK sticks to be heat-damaged.

If the stick is working right, it will feel slightly warmer than room temperature and all the cells will be the same temperature during the process. It should also charge to about 6,400 mAh when full and do it in a bit more than one hour from a minimal state of charge (0.8 V per cell). If all goes well, the final numbers in the display will be about 6,400 mAh charged, and 5,700 to 6,100 mAh discharged. If you have any sticks that vary greatly from these values, treat them with suspicion and mark them as problematic.

It is best that all the sticks in your pack discharge to about the same level. Very odd discharge characteristics in some sticks will drag down the better ones, causing the dreaded IMA warning light to come on sooner than it would otherwise. However, a 100 to 400 mAh difference will not present a significant problem to the car's computer. None of the sticks will have exactly the same discharge value no matter what you do.

Battery Reconditioning Cost

Item	Cost
Used battery pack from junkyard	$315
Charger/reconditioner, iMax B6	55
Torx socket, #30	6
Electrical energy (10¢ per kWh)	4
Total	**$380**

The End Result

At the end of a month of reconditioning, six bad sticks—out of the 20 in the pack—showed up, which explained a lot as to why the car functioned so poorly. Each failed stick was either excessively slow to charge or only at a partial charge after the machine said it was done. During cycling, poorly performing sticks will also get much warmer than correctly performing ones. Heat is one of the items that triggers the IMA warning light on the dashboard.

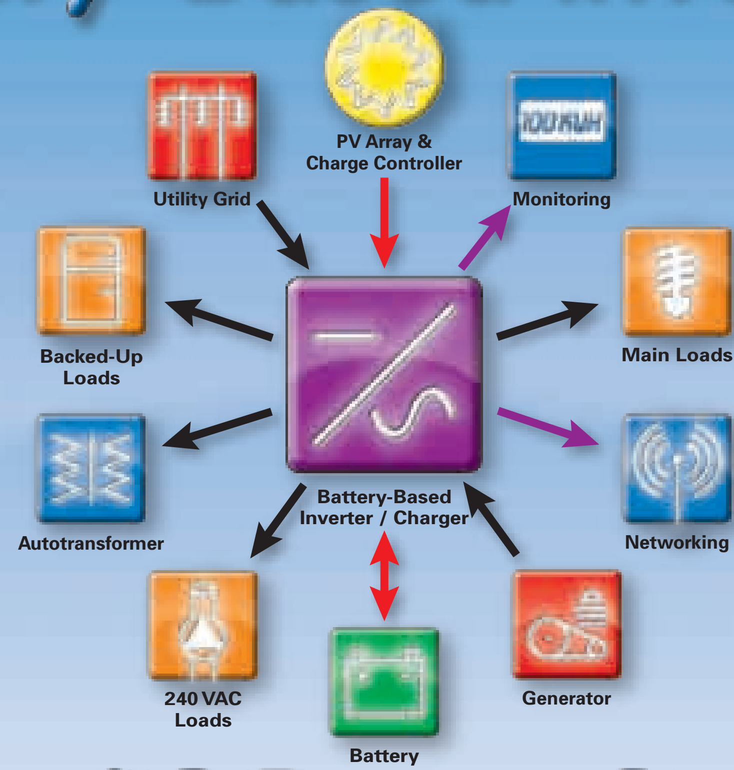
The next step was finding replacement sticks. I had to replace 30% of my battery pack and the most cost-effective way was to buy a junkyard battery pack and put it through the same charge-discharge process to find its good sticks. This took another 25 days, but was well worth the effort—the car now runs like new, gets 50 to 55 mpg on the highway again, and all the computer errors have vanished. I also have 12 good spare sticks for the next time I need to do this—probably in three to four years, judging by how long the original battery lasted before the computer errors showed up.

Failing IMA packs can also cause seemingly unrelated computer errors, like oxygen sensor failures and a 12 V battery error. The 12 V battery charges from the IMA pack through a DC-to-DC converter—my best guess is that the car's computer uses it as a reference voltage to judge how well some of the car's other sensors are working. In any case, all of the original error codes went away after the IMA pack was refurbished.

Access

Michael Lamb (michael47lamb@gmail.com) is a professional handyman who loves tinkering with electrical things. After 10 years working at the Energy Efficiency and Renewable Energy Clearinghouse as a consultant, he retired to tinkering full-time.

Battery-Based Inverters:



Using AC Power Sources & Other Tips

by James Goodnight

Modern battery-based inverters offer more than just a DC-to-AC power conversion—they can charge batteries, select from multiple power sources, and control external functions. Here are a handful of common features and what they can do for your RE system.

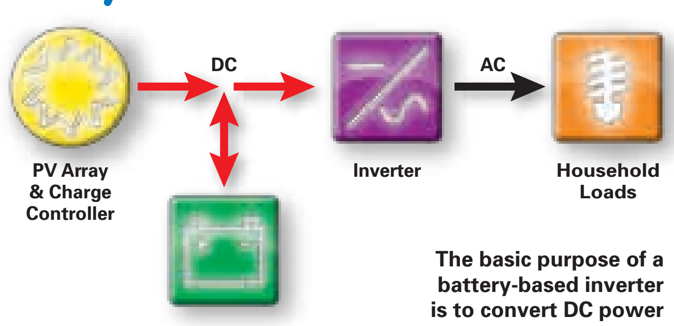
Integrated Battery Charging

A battery charger in a battery-based inverter greatly enhances the inverter's versatility and utility. First, it provides an alternate means for charging the battery bank from a power source other than the sun, which is useful in times of short days, poor weather, and/or high loads. It also increases complexity, weight, and cost, but the additional application flexibility usually outweighs these negatives. Several inverter manufacturers offer inverter/chargers, including Schneider Electric (formerly Xantrex), Magnum Energy, and OutBack Power.

Connecting to an AC Power Source

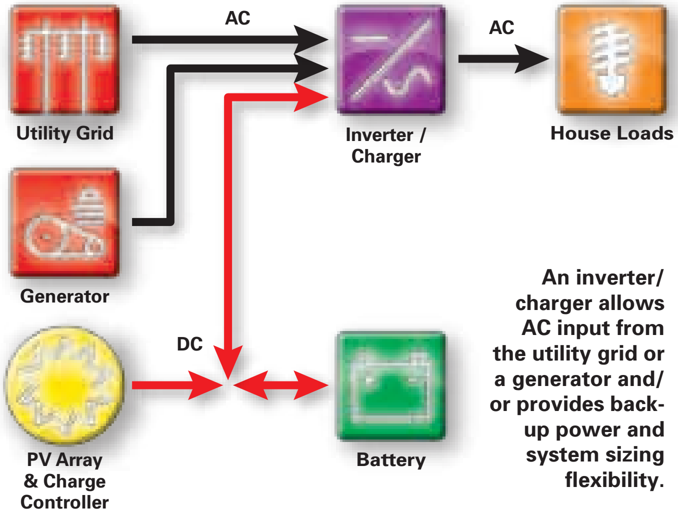
Connecting an inverter/charger to an AC power source opens up a whole new realm of application flexibility. Generators have been the most common backup source for off-gridders, and they can enhance system performance and flexibility. A generator can be used to power large, infrequent loads.

Inverter in a Basic RE System



The basic purpose of a battery-based inverter is to convert DC power for use by AC loads.

An Inverter/Charger Allows AC Input



An inverter/charger allows AC input from the utility grid or a generator and/or provides back-up power and system sizing flexibility.

During a stretch of cloudy weather, it can simultaneously power loads and help recharge the system's batteries. A generator can decrease the cost of a PV-based system by allowing it to be sized for average annual insolation rather than for low winter daylight hours. And, if the batteries or inverter fail, a generator can serve as a stand-alone backup to the inverter system.

An inverter/charger can similarly use energy from the grid for backup, or be connected to the grid *and* a backup generator via a transfer switch, which may be internal or external. This capability can meet a wide range of useful applications and benefits. A PV-based RE system is still used to power designated loads, but the grid can provide a seamless backup. And in the event of cloudy weather and a grid failure, a generator provides yet another layer of backup.

One method of doing this is with "low battery transfer"—if the battery voltage falls below a predetermined set point for a prescribed period of time, the inverter/charger automatically transfers loads to an AC source and turns on the battery charger. When the battery voltage exceeds the "high" set point for a prescribed time period, the inverter transfers the loads from the grid back to the battery bank.

Types of Wave Forms

Common inverter types include modified square wave (MSW) and sine wave (SW). MSW inverters are inexpensive, but their wave form is not compatible with some sensitive electronics, and may cause them to overheat or suffer other damage. SW inverters deliver a wave form of equal quality or better than that from the grid, and are therefore recommended for the applications described in this article.

Best Matches for a Basic Inverter

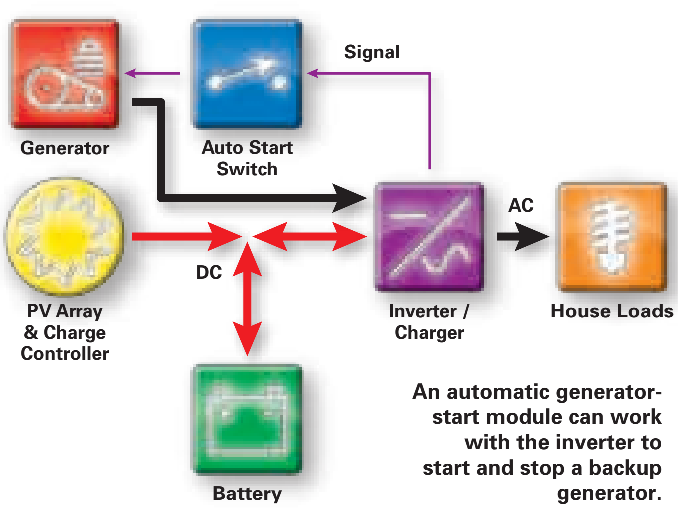
The most basic battery-based inverter converts DC (from a battery bank) into 120 VAC at 60 Hz to supply common household appliances. These basic units are common in off-grid applications, especially in part-time homes and RVs with limited electrical loads.

The systems these inverters go into are relatively simple and inexpensive to design, install, and maintain. Typically, the inverter does not include a built-in battery charger for supplemental battery charging, but relies solely on the RE source to power loads and recharge the batteries. That's why they're best paired with small RE systems for vacation cabins and RVs.

But standard, no-frills inverters have their limitations. They are usually not a good choice for PV systems where solar insolation is highly variable. Similarly, they're not a good match for powering large loads (which drain the battery bank quickly), since without backup, the power source won't be able to keep up on a daily basis. Critical loads (for example, those that must have power regardless of weather patterns) are not good pairings with a "basic" inverter, either.

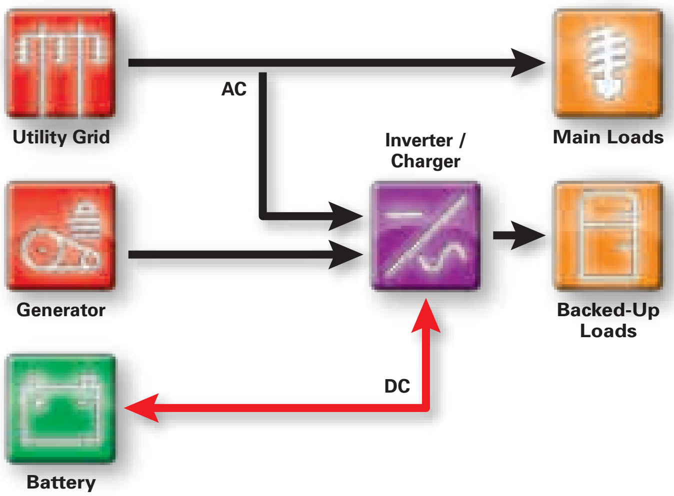
Other methods border on "smart grid" status. For example, a "grid use" feature can be set to instruct the inverter when to connect to the grid. Typically, this setting coordinates with time-of-use (TOU) billing, connecting loads to the grid when rates are low to operate AC loads and perhaps help recharge the batteries. When TOU rates are high, (usually during daylight hours), the inverter/charger disconnects from the grid, and the RE power source and the batteries power AC loads. The result is reduced peak demand and lower utility bills, with a reliable and quiet backup system.

Automatic Generator Start



An automatic generator-start module can work with the inverter to start and stop a backup generator.

Grid and/or Generator and Battery Backup, without RE



When a PV system is impractical and the grid is unreliable, a scaled-down hybrid system with a stand-alone inverter/charger may be the answer.

"Grid support" capability uses the RE system to reduce power consumed from the grid. When the inverter recognizes that the solar charge controller has completed its bulk-charge cycle and is operating in absorb or float mode, the inverter then diverts any excess production to power AC loads, thereby reducing AC power supplied by the grid—while the RE system continues to recharge the batteries.

"Peak shaving" initially uses grid energy to supply loads up to a set AC current limit, but then draws on the RE source to provide additional energy if required. This can help reduce use of peak rate utility energy (i.e., surge demand or top-tier TOU), while maintaining the battery bank at a high state of charge as a backup source.

Another sophisticated inverter feature is the AC source input current-limit setting, which limits the total current that will be drawn from an external power source such as a generator, thereby keeping it from being overloaded. If the sum of the regular AC load current and the charger's AC current exceeds the setting, the inverter "backs off" the AC current drawn. In effect, the charger becomes a variable "opportunity" load.

For example, if the AC loads draw 25 A, and the charger is set to draw 10 A, but the input current limit setting is 30 A, the inverter will reduce the charger load from 10 A to 5 A to keep the total load current at the 30 A limit. However, if a 5 A load is turned off and the downstream AC load total is reduced to 20 A, the inverter will increase the charger load to its 10 A setting, and the total current will still be at or below the 30 A input limit.

The issue here is that the combination of loads might exceed a generator's output current rating. It's usually no problem to pull 40 A from the grid, but a generator may only be able to supply 30 A. Setting the AC input limit helps prevent the generator from being overloaded. Some inverter/chargers have two AC input settings: one for "AC 1," i.e., the grid, and another for "AC 2," the generator.

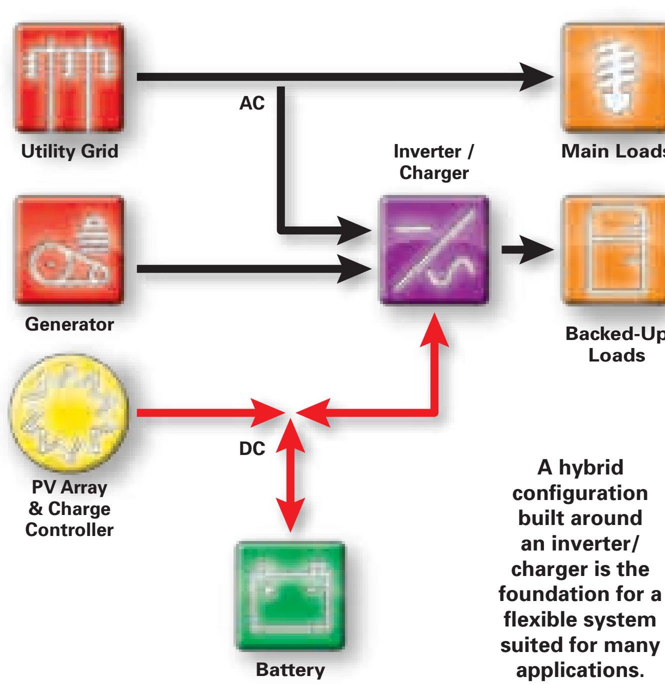
These features allow system owners with access to the grid to install and gain from RE systems without having to sever all ties with the grid. The system size can be influenced more by space and budget than by absolute power requirements and location. The owner uses some amount of renewable energy, has backup for assigned loads, and utility electricity use and cost are reduced.

It's also possible to use these features to suit other situations. For example, if a PV system is impractical and the local grid is unreliable, then a scaled-back battery/generator system without RE may work—basically, it'll be a big uninterruptible power supply (UPS). This approach offers flexibility in sizing, operating, and maintaining the inverter and battery bank—and adding a PV system at a later date can be fairly easy.

Controlling External Functions

Other battery-based inverter features often include an auxiliary output connection (AUX). Common AUX applications include a "Fan" or "High Battery V" setting to ventilate a flooded-cell battery bank enclosure, exhausting hazardous hydrogen gas released as the batteries are recharged. When the grid is down or for a system without a backup power source, a "Load Shed" setting can be used to disconnect a noncritical load, minimizing battery damage if the battery voltage falls below a set point. For example, if specific circuits for non-essential lights, fans, pumps, hair dryers, etc., are disconnected when the battery state of charge (SOC) drops to 70%, then remaining battery energy is conserved for powering essential loads such as necessary lights, a fridge, and communications equipment.

PV, Grid, and Generator Hybrid with a Multifunction Inverter



A hybrid configuration built around an inverter/ charger is the foundation for a flexible system suited for many applications.

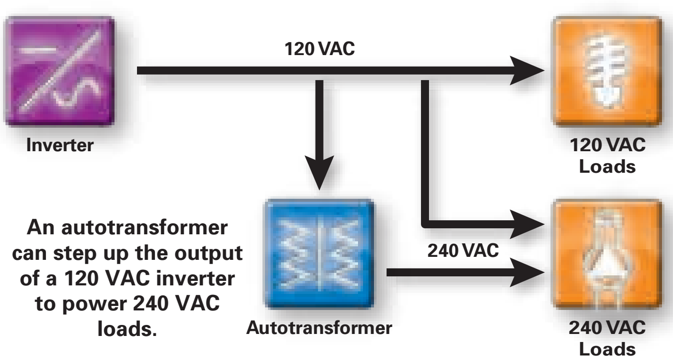
Alternately, this feature could be used to signal the system's owner that the batteries are getting low and corrective action based on loads and weather patterns may be required.

An automatic generator start (AGS; usually an optional module) feature is used to automatically start and stop a backup generator according to a wide range of parameters, including day of the week, time of day, battery voltage, scheduled exercise, etc. Some inverter/charger manufacturers offer their own optional AGS module; others may require a third-party solution such as an Atkinson Electronics Generator Start Control Module.

Powering 240 VAC Loads with 120 VAC

While some battery-based inverters are available with 120/240 VAC output, with a little outside help, a single-phase 120 VAC inverter/charger can power a 240 VAC load by connecting an autotransformer to the inverter's output. This is a popular and cost-effective application for systems that have mostly 120 VAC loads but need to occasionally power a 240 VAC load, such as a well pump. In this example, placing the pressure switch, which will disconnect the 240 VAC pump when the water storage tank is full, between the inverter and autotransformer eliminates the transformer's standby loss when the pump is not operating.

240 VAC with an Autotransformer



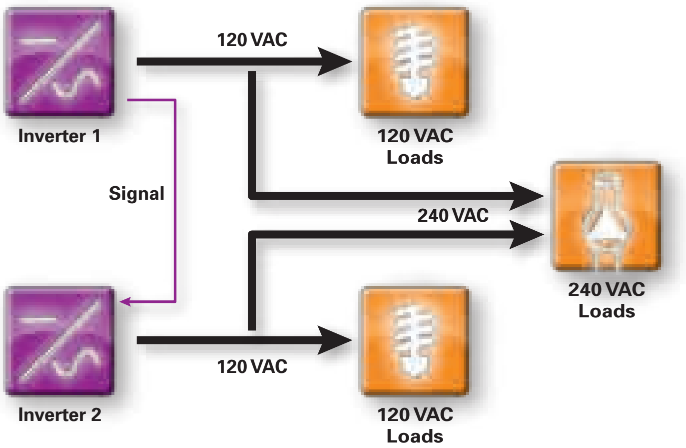
An autotransformer can step up the output of a 120 VAC inverter to power 240 VAC loads.

Stacking

Despite all of these features and flexibility, a single inverter/charger sometimes just isn't up to the task of large loads. Fortunately, many manufacturers' models can be "stacked" to deliver more power, either through higher voltage (changing 120 VAC to 120/240 VAC), more current, or both. By networking a pair of 120 VAC inverters, their outputs can be wired in series to supply 120/240 VAC split-phase power. Similarly, a pair of 2,500 VA, 120 VAC inverters could be stacked in parallel to provide up to 5,000 VA at 120 VAC.

A potential drawback to operating multiple inverter/chargers is that their collective idling losses can really add up. For example, a single inverter idling at 20 W will consume 480 Wh per day (20 W × 24 hrs./day). Two inverters idling would consume almost 1 kWh each day. Fortunately, these inverters are typically smart enough so that standby units can be user-programmed to "sleep" in a very low-power mode (about 3 W instead of 20 W) when loads are low. They wake up and assist the main inverter when loads exceed what a single inverter can handle, but then return to their low-power sleep mode when loads are once again reduced.

120/240 VAC with Stacked Inverters



Stacking 120 VAC inverters can provide both double the maximum power, and 240 VAC for larger loads.

Independent Inverters

Another multi-inverter strategy can reduce whole-system inverter losses and increase low-power efficiency. A smaller inverter, without a built-in battery charger, is selected to efficiently run a range of regular and/or always-on loads, like CFLs, answering machines, cordless phones, and Internet routers. A large inverter/charger is also connected to the battery, but is used to power large (usually, short-term) loads, such as a microwave oven or shop tools, connected to circuits isolated from the small inverter. It's only turned on when it senses a load via its low-power "search" mode. Using two inverters also provides an additional measure of equipment backup should one fail, and the larger inverter/charger can help charge the batteries if required. Exeltech, Samlex, and Schneider Electric (Xantrex) make smaller sine wave inverters useful for this strategy.

Networking & Monitoring

Inverter/chargers typically offer their own networking features, and there are also third-party solutions for monitoring and some amount of remote control. Networking is required to connect control and display devices; to facilitate most AGS functions; to share common data (i.e., battery temperature); to coordinate operation of multiple devices (i.e., inverters and charge controllers); to troubleshoot system maladies; and, often, to set or adjust system parameters such as input current limits, battery charger set points, and AUX operation.

Monitoring allows a user to track system operation and performance, diagnose potential problems, and sometimes control functions. Monitoring is available locally via a PC, and some products offer remote capability. Examples include greenHouse Computers, Right Hand Engineering, WattPlot, and APRS World.

System Networking and Monitoring

Networking and monitoring features allow system components to interact and display data to the user and/or installer.

Choosing Your Features

Not all of these features are available from every battery-based inverter/charger, and multiple features can't necessarily be used simultaneously. When you're ready to meet the needs of your particular application, download the user manuals for several inverters, give them a good read, and then contact your dealer and/or the manufacturers for additional information. Additionally, online assistance may be available from manufacturers, and independent forums and list servers. You'll then be on your way to a system configuration that offers a variety of practical features to help provide improved system performance and convenience tailored to your particular needs.

Access

Jim Goodnight (james.goodnight@us.schneider-electric.com) has more than 35 years of design and project management experience, covering a broad range of technical fields. He has been designing and optimizing PV systems since 2002. He began providing technical consulting and field support to OutBack Power Systems in 2004, and formally joined the company in 2008. Jim joined Schneider Electric in 2010 as a senior sales application engineer.

Inverter Manufacturers:

Atkinson Electronics • www.atkinsonelectronics.com

Exeltech • www.exeltech.com

greenHouse Computers • www.greenhousepc.com

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OutBack Power Systems • www.outbackpower.com

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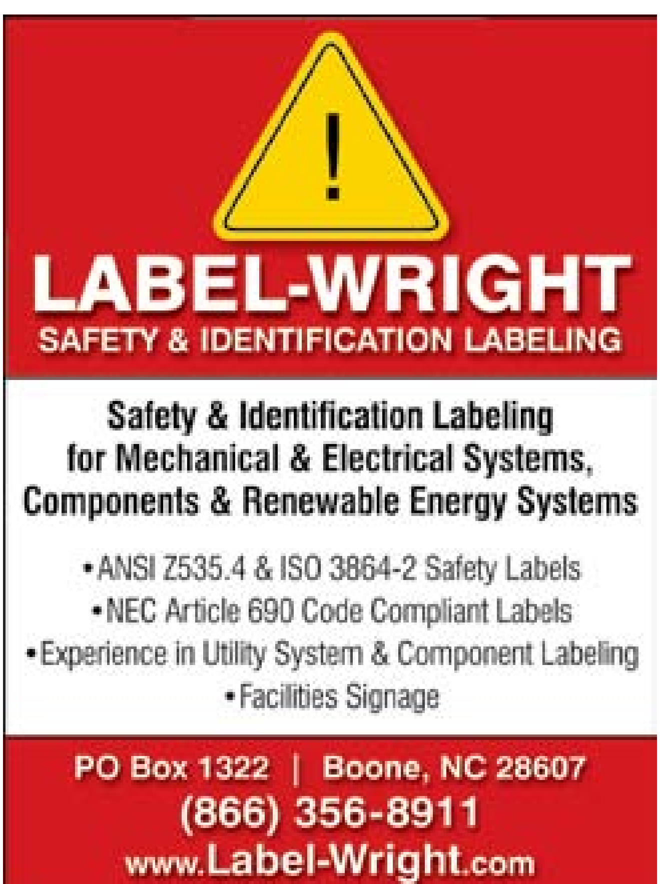
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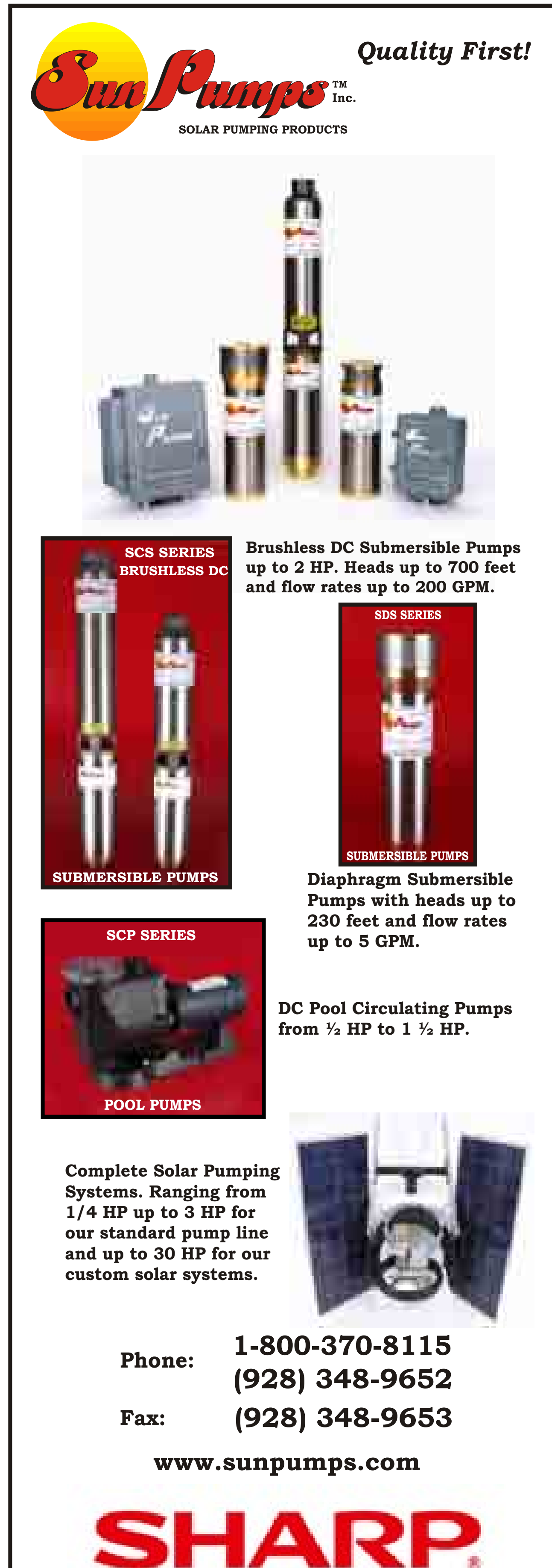
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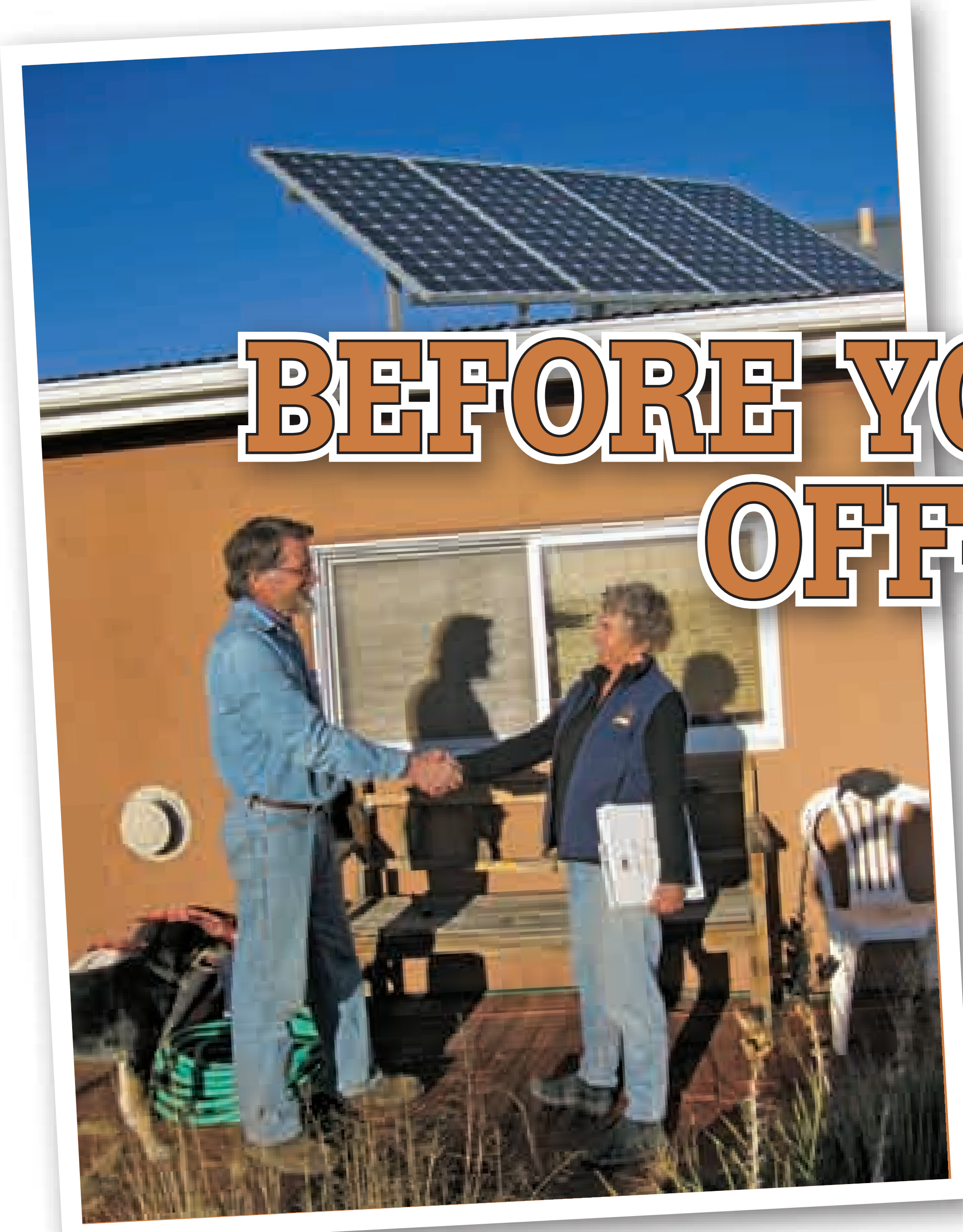

BEFORE YOU GO OFF-GRID

by Allan Sindelar
photos by Lael Eccard

An experienced off-grid installer can help make sure you get the system that meets your needs.

Seasoned pro Allan Sindelar shares his approach to designing high-performance off-grid systems: what works, what doesn't, and how to select a top-notch installer.

Just a few years ago, most solar installers specialized in off-grid systems, for homes beyond the utility lines. Now, most new solar companies only do grid-tied systems because the largest customer growth has been with residences and businesses with access to the electric grid.

But the two system types are very different, and the skills needed to design, install, and support the two are likewise distinct. Off-grid knowledge is gained through lengthy experience, and many newer solar companies (and those serving only urban markets) simply don't offer off-grid services. If you're considering an off-grid RE system, here's what you need to know to successfully hire a pro.

The Relationship

Working with an off-grid installer is akin to entering a long-term relationship, and it does not end with the installation. Depending on your technical skills, you may need your installer to guide you through the system's long-term care, and you may need to call on your installer when problems arise. You will want to feel confident that your installer will support you and your system for years to come.

A good designer-installer will generally start with an initial conversation, either in person or by telephone. Answers to these questions are important to the design process:

The interview process is critical to getting an off-grid system that performs to your expectations.

- Do you already have the property, or are you still in the process of looking for land or a home? (This helps your designer understand what information you'll need.)
- Where is the property? (If it is far away, a good dealer will often suggest another installing dealer closer to you.)
- Is there an existing home or other building on the property, or are you planning to build a new home?
- What, if any, RE equipment is already in place? Can you provide digital photos of the existing PV system?
- If you are building a new home, are you doing the work yourself or are you working with a general contractor?
- Will this be your full-time residence or a vacation home?
- If you are building new, how far are you into the design or building process? (Your designer is best included in the RE design process from the beginning.)
- What are your motivations for wanting to be off-grid? Is it your only option due to your location? Are you concerned about utility outages or future rate hikes?
- How far away is utility power and what would it cost to bring it in and hook up to it?
- Do you have specific needs related to your lifestyle and life situation, such as young children or elder care, plans to work at home, livestock, etc.?
- What do you know about off-grid living?
- How will you heat your home?
- What are your water supply needs, and is any equipment in place now, such as a well?
- What budget range do you have in mind, and how will you finance your project?

SHOPPING FOR OFF-GRID PROPERTY

Here are a few issues to consider when searching for your off-grid paradise:

Most off-grid properties are remote, which likely means far from town services. As you consider a parcel, consider if its remote location will necessitate excessive driving.

If the property has reliable grid power at its edge or nearby, consider tapping in. Build your home as if you will be off-grid—that is, with the sensible energy efficiency of an off-grid home—then hook to the grid and install a grid-tied system to offset your utility electricity consumption. You will spend less, reduce your impact by letting the utility take the place of a backup generator, and have less maintenance and battery replacement expense.

If buying a home with an existing RE system, consider having the system professionally inspected, just as you would have the home inspected. An existing system may have served its former owners well, but may be totally inadequate for your needs, or antiquated and difficult to maintain. Few home inspectors are qualified to evaluate RE systems; use this opportunity to get to know an installer to see if they are right to upgrade the system.

If buying an existing on-grid home, it is probably best to leave it on-grid. Taking an existing home off the grid is a difficult and expensive task, as many prior decisions—about siting, appliances, water supply, and heat, to name a few—were likely made without consideration for future off-grid possibilities.

A professional installer will use site survey tools to find the best location for the PV array.

A thorough load analysis takes the guesswork out of system sizing.

Besides providing a good initial profile of what you are seeking, and at what level of technical detail your designer should address your questions, a seasoned off-grid installer often hears more "between the lines" than is verbalized. They can often sense (and answer) the questions you don't yet know to ask, and may even nudge you to revisit the idea of grid connection, if they feel you don't have a realistic picture of the responsibilities involved in maintaining an off-grid system. Don't be offended—you would save money and effort by discovering this early in the process. (Note: While there are no monthly electric bills, off-grid living is seldom cheaper than utility power, as amortized battery replacement costs often match utility charges.)

Depending on the property's location, an installer may also assess your reasons for wanting to live off the grid, and how feasible that might be for you. If you have not yet settled on a property, they may advise you of some things to consider when looking for your site, such as a building site with unfettered solar access (see "Shopping for Off-Grid Property," previous page).

Most installers do not charge for an initial consultation, which usually lasts about an hour. Think of it as a "mutual employment interview"—at its conclusion, you and your installer will have a pretty good sense of your compatibility, and will decide together whether to move on to the next steps in the design process.

Load Analysis

A load analysis is the next essential step in the off-grid design process, providing the hard data necessary to build a system that will efficiently meet your energy demands.

You must provide your designer with a comprehensive list of everything you expect to power in your off-grid home—that means every light, appliance, and mechanical component, big and small. The expected power consumption of these loads and hours of use are summed and averaged to estimate daily energy consumption. This becomes the basis for the system size and design. (For more information, see "Getting Started with RE: Professional Load Analysis and Site Survey" in *HP120*.)

Most PV system installers or dealers use spreadsheets or fill-in-the-blank forms to walk clients through the process. Besides paper calculations, consider purchasing an inexpensive watt meter that measures power use and energy consumption.

For system designers, a load analysis serves four purposes:

- Lists and quantifies loads so the system can be sized to meet the home's needs.
- Helps identify ways to achieve end results more efficiently to use less energy. The process is a vehicle for your designer to educate you about off-grid living, including lifestyle changes for greater energy efficiency. It often includes replacing inefficient appliances. For example, if you like a big-screen TV for watching sports, consider a second smaller, more efficient one for most shows, saving the large screen for full batteries and Super Bowls (see "Toast, Pancakes, and Waffles: Planning Wisely for Off-Grid Living" in *HP133*).
- Helps identify overlooked or inappropriate loads, potential problems, and special cases; and suggest alternatives that use less electrical energy. Examples include hot tubs, which, in off-grid situations, usually are heated with wood or gas, not electricity.
- Creates a record of how much energy use was expected in case changes are called for. Consumption can be reevaluated, and loads reduced or the system expanded accordingly.

THE DYNAMICS OF OFF-GRID DESIGN & INSTALLATION

Most off-grid installations and substantial system upgrades are arranged and completed directly with homeowners. But some projects require that the installer work through a general contractor, who is responsible for planning and executing the entire building project, including hiring, coordinating, and scheduling subcontractors.

Typically, each subcontractor completes one aspect of the job with little coordination with other subcontractors—and little understanding of specific off-grid efficiency needs. The result often is that each system—heating, appliances, AC wiring, etc.—works well but the home wastes a fair amount of electricity.

If you've hired a general contractor to coordinate your building project, insist that your RE installer remain involved from the onset of the design process, and encourage collaboration among the various subcontractors—especially those involved with the electrical, lighting, water pumping, and heating.

Key systems, such as lighting and heating, should be designed as a team of contractor, subcontractors, and PV system designer. The PV designer reviews nearly all of the design decisions and appliance selections for compatibility with the finite energy available. He or she will also make sure the array will be installed in a location to maintain its solar access.

Teaching the customer to understand and operate their system is crucial to post-installation satisfaction.

For the client, a fifth benefit arises that is the most important of all—a valuable self-education process. Most of us who live with utility power take energy availability for granted. We use it as needed and pay the bill each month, and we have had little reason to assess our energy use. Doing a load analysis can be an eye-opening activity, since some folks are quantifying their energy use for the first time and may need to reevaluate whether their energy habits are compatible with off-grid living. Additionally, even if the client decides to stay on the grid, they are now armed with information on how to reduce monthly energy bills, which with minimal or no investment can save on future energy bills and reduce the home's environmental footprint.

Load analysis is a rigorous and time-consuming process, but necessary. By establishing clear expectations of your solar electricity demands, you are far more likely to be satisfied with the final product and can better understand your system's limitations.

Budget

Good wind and hydro sites are rare—for most folks, their off-grid resource defaults to the sun. (To simplify the discussion, that's what we'll focus on, although some off-grid folks will implement hybrid systems to meet their energy needs.) Off-grid PV systems can cost as little as $3,000 or more than $100,000. Big or small, the design and education processes are generally the same.

Most clients initiate the budget conversation by asking for ballpark figures. They'll ask what they think is a seemingly straightforward question, like "How much would it cost to power a 2,000-square-foot home?" What they don't realize is that the size of the home is nearly irrelevant to the question being asked. Two homes of the same size can have electrical needs that differ by a factor of five or more, since a home's energy use is largely dependent on how the occupants use it.

Regular maintenance of off-grid systems is taught by the installer, and needs to become a habit.

An off-grid system's cost can vary greatly depending on the loads, lifestyle, and budget of the customer, and what renewable resources are available. A typical modern, full-featured, code-compliant off-grid solar-electric system for a customer who has properly reduced loads has at least a 1 to 1.5 kW PV array and a battery with three days of storage capacity. A system that size can cost between $15,000 and $25,000, including all components, design, labor, and support. It usually excludes appliances and a backup generator, carpentry, excavation, and concrete work, as these are usually best done by you or by another tradesperson at lower cost. Generally, wiring only includes connection to the home's breaker panel—PV installers usually don't install conventional household wiring.

If the budget exceeds your out-of-pocket expectations, your installer may be able to advise you of financing resources that others have used successfully (see "How to Finance Your Renewable Energy Home" in *HP103*). Federal tax credits of 30% for residential solar and 30% for efficiency upgrades apply equally to grid-tied and off-grid systems. While some incentives apply only to homes with utility power, many states offer incentives and tax credits, and few distinguish between the two system types (see www.dsireusa.org). A good installer will explain available incentives and guide you through the application process, as well as pull permits and secure inspections.

Beware of Bargains

Factors that affect a PV system's overall cost include the amount of power produced daily, inverter capacity and waveform quality, and battery bank size and quality, the inclusion of details like surge arrestors and battery vent fans. PV hardware follows some pretty traditional rules: You get what you pay for—and quality is usually worth the extra cost.

Use the questions in this article as a guide to understand the issues involved in creating a good system. Then interview several installers in your area. Who has the most off-grid experience? Who has the most satisfied customers, and can provide references?

Initially, don't ask what the system will cost. A good designer can only answer "it depends" until a full load analysis and interview is done. Inexperienced or unscrupulous installers will respond with a low initial figure, knowing that the goal at this early stage is to "get the job."

Use your research to select a good designer/installer; then work with him or her to develop your particular system according to your loads, lifestyle, and budget. If the installer you have selected and chosen to trust tells you that your system will cost more than you can afford, work to reduce your loads or forego certain luxuries. Shopping for a cheaper system is usually a false economy and may prove disastrous.

Site Visit & System Design

Once your installer has a general idea of your loads, lifestyle, and budget, a site visit is next. Survey tools are used to determine one or more possible sites for your RE system. The installer will also measure conduit and wire runs, select a location for equipment and batteries, look for potential pitfalls to avoid, locate your water well, plan for a backup generator, and formulate a general plan for the installation.

Next, the installer will design the power system. Most will already have a good idea of what components will be used in your system—the bulk of the design process involves performing sizing calculations, resolving specific issues, and working through the various design subtleties. Your designer will let you know if your budget isn't adequate to cover the system you'll need to meet your loads. Once such issues are resolved, your installer will prepare a proposal for you. It will likely include component descriptions, an estimate of expected performance, inclusions and exclusions, estimated price, and terms of payment. Knowing your desired budget range will help your installer keep the proposal in line with what you can afford.

Because of the legwork involved and the custom nature of off-grid system design, most installers won't provide "free estimates"—after all, you are purchasing their knowledge and experience, as much as the equipment. You may expect the design process to make up 2 to 5% of the overall system cost—that's $400 to $1,000 on a $20,000 system. Some will credit part or all of this fee if you buy the system.

Many experienced installers will refuse to install equipment purchased elsewhere, such as from an Internet retailer. Why? The installer would lose control over design and equipment specifics, yet still be responsible for the system's care. Plus, warranty issues might have no clear resolution: Was a component failure the result of a defect, poor system design, or an incorrect installation practice? Also, the profit on hardware will have been given to a third party who has little incentive to support the end user.

Installation & Commissioning

A good installer will stay in touch as the installation days approach. Questions will arise, changes may be necessary, and the starting date may move up or back. Your installer may encourage you to be present and available during installation, to deal with questions that you can best answer. You may be asked to help out from time to time, if only for simple tasks. If you lend a hand it becomes "your" system with your time invested, and as you watch it come together it becomes less forbidding and mysterious.

Once installation is complete, the system is methodically powered up. Next come programming the inverter, charge controller, and system monitor, and the myriad details to complete the job. Your installer should include a high-quality shunt-based system monitor, preferably located in a commonly used location in your home, rather than out with the power equipment. If this is your first off-grid experience, your installer may initially teach you just the basic use of your monitor so that you can live within your energy budget. In a month or so, once the system is more familiar, a good installer will return to present additional maintenance guidance. You should expect a full owner's manual with all component manuals, design records and notes, maintenance procedures, warranties, and copies of any inspection reports or permits, but this may not be ready until after the system is operational.

Expect some support as you become familiar with your system's capacities and limitations. You will likely have questions and may encounter problems—this is normal, and you'll need your installer's assistance. Better installers warrant their work and support manufacturers' warranties as well.

A system that's done well will give you the tools to live well, with minimal dependence on fossil fuels. You will have gained an appreciation of how to use electricity wisely, and how to match your living habits with the natural rhythms of weather and season—a wonderful way to live.

Access

Allan Sindelar (allan@positiveenergysolar.com) installed his first off-grid PV system in 1988, founded Positive Energy Inc. of Santa Fe, New Mexico, in 1997, and has lived off-grid since 1999. He is a licensed commercial electrician and a NABCEP-certified PV installer.

Suggested Reading:

"Starting Smart: Calculating Your Energy Appetite," by Scott Russell, *HP102*

"Toast, Pancakes, and Waffles: Planning Wisely for Off-Grid Living," by Allan Sindelar, *HP133*


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Grounding & UL Standard 1703

by John Wiles

One of the most important elements to long- and short-term PV safety is grounding. Environmental conditions, using copper conductors to ground aluminum module frames, and the daily thermal cycling that terminals, combiners, and modules are subjected to will eventually cause a breakdown in insulation or in the electrical connections. That means proper grounding is a must. Here's why.

Grid-tied residential, commercial, and utility-scale PV systems operate with DC voltages from 50 to 600 volts—and higher. AC voltages start at 120 V and some larger systems, such as premises wiring in large commercial and industrial facilities, can hit 23 kV. Exposed circuits operating at more than 30 V (DC or AC) in wet locations are considered a shock hazard by Underwriters Laboratories (UL), which helps establish safety standards for various products. [See also *National Electrical Code* sections 690.31(A) and 690.33(C).]

PV system current ranges from less than 10 A (DC and AC) to about 2,400 amps DC on some of the larger inverters. Consider this: In the right material, an arc at only 1 amp can start a fire. Modules commonly used in residential PV systems range from 20 to 320 W—considerably more than 1 A. PV modules can produce dangerous voltage and current throughout their 40- to 50-year life expectancy. USE-2 cables and the new PV cables are some of the toughest cables available—when properly installed, USE-2 cables have been reported to still be in good shape after two and half decades of service. But what about a less-than-outstanding installation after 30 or 40 years?

Grounding Problems Reported

There is significant confusion among module manufacturers, installers, and inspectors concerning how to properly ground PV modules. Inspectors are finding improper grounding techniques, and improper grounding instructions are appearing in listed PV module instruction manuals.

Unfortunately, it is difficult grounding PV modules and racks in a manner that will yield a low-resistance connection and will last for 50 or more years. Inspections and tests have found that in some cases, module-grounding connections have deteriorated in as little as three years.

Bonding vs. Grounding

The current edition (2002) of UL Standard 1703 (PV Flat Plate Modules) devotes a single section to bonding and grounding. Bonding refers to the *factory-made* electrical connections between the four or more sections of the aluminum frame. Grounding refers to the *field-installed* electrical connection between the aluminum module frame and the equipment-grounding system (usually copper conductors).

The module bonding screw and the braided copper is touching the aluminum frame, causing corrosion. Tinning the copper does not help.

Bonding uses specific materials and methods to attain a durable electrical connection between the frame pieces. Any failure in module or conductor insulation may result in all pieces of the frame receiving equal voltage. When the module frame is properly field-grounded at one of the marked and tested points, factory bonding also ensures that the entire module frame is maintained at the ground potential under fault conditions. All bonding fasteners are precisely torqued to specification by automated equipment or trained technicians. During the listing process, the factory's bonding materials and methods are evaluated for low resistance and durability. If the manufacturer changes any of the bonding materials or methods, the changes must be reevaluated by the listing agency.

Contrast this precisely controlled and evaluated system with the field-grounding techniques used to connect a copper equipment-grounding conductor to the aluminum module frame. Grounding PV modules is haphazard at best. Many

module manufacturers don't acknowledge the importance of this connection to the system's overall safety. Many instruction manuals and hardware (sometimes supplied) show techniques that may not provide good electrical connections. Further, field-made connections using a threaded fastener are rarely torqued to the specified value—even when that value is given in the module instruction manual—because few PV installers have torque screwdrivers. Inspectors may not inspect the grounding connection and they are rarely tested for overall continuity. Also, since the PV system can operate without trouble for many years, there is little motivation to inspect these connections after the original installation. But possibly the most critical factor is that the UL Standard 1703's bonding/grounding section does not clearly distinguish the differences.

When other good methods are unavailable, use surface preparation and a tin-plated copper lay-in lug listed for direct burial, and a torque screw driver for accurate tightening.

Instruction Inconsistency

In late 2007, UL issued an "Interpretation" of UL 1703 that focused on module field-grounding to be used by module manufacturers and certification laboratories to evaluate and possibly revise the grounding methods, hardware (if any), and instructions supplied with the modules. Modules are supposed to be reevaluated every five years (when the listing must be renewed). Unfortunately, it is not possible for the laboratories to review all existing modules.

For example, some instructions specify lock washers, star washers, and other critical grounding hardware that is found at hardware stores that lack control over the quality of the supply. Others recommend thread-cutting or thread-forming screws, but the UL interpretation states that all threaded fasteners must be installed and removed 10 times without damage to any threads—nearly impossible to do with aluminum module frames.

The UL 1703 interpretation contains a chart showing the compatibility of various metals—electrolytically incompatible metals are clearly shown. For instance, copper and aluminum should not come in contact—if they do, the aluminum at the contact point will suffer galvanic corrosion, destroying the connection. (Inadvertent contact between the copper grounding conductor and an aluminum module frame or rack does not pose problems because the small amount of aluminum that may be corroded is part of the electrical contact.) But some module manufacturer instructions call for isolating the copper conductor from the aluminum frame by using a stainless steel washer—without specifying surface preparation of the oxidized, anodized, and/or clear-coated aluminum module frame. Done properly—that is, *with* surface preparation—the presumption is that the mechanical fastener (screw and nut) and the stainless steel washer would carry the fault currents. However, these devices have not been evaluated and listed for carrying current.

To further confuse the situation, it appears that the high currents, steel plates, and test methods used in UL Standard 467 for evaluating and listing grounding devices may not be applicable to evaluating grounding devices for PV modules and racks where the currents are low and the aluminum surfaces are oxidized, anodized, or clear-coated.

UL is developing specific UL Standard 1703 requirements for PV module grounding that will appear at some future date. The requirements will cover methods and hardware supplied by the module manufacturers, as well as third-party grounding devices.

For now, when the grounding instructions furnished by the module manufacturer are inadequate or contradict *NEC* or UL requirements, the PV installer and the inspector must work out an acceptable module grounding method and hardware. One method used by utility companies for many years to connect copper conductors to aluminum bus bars in an outdoor environment uses surface preparation and a tin-plated copper lay-in lug listed for direct burial. It may be found in the Burndy instructions for installing lay-in lugs and in Appendix G of the *NEC/PV Suggested Practices* manual. Both may be found on my Web site (see Access).

Although this copper ground appears installed per the module's instruction manual, the copper is touching the aluminum frame which will corrode the aluminum and destroy the electrical contact.

Access

John Wiles (jwiles@nmsu.edu; 575-646-6105) works at the Institute for Energy and the Environment (IEE) at New Mexico State University, providing engineering support to the PV industry and a focal point for PV system code issues. For PV and code training programs (which qualify for NABCEP continuing education credits), visit the STDI Web site at www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/Codes-Stds.html

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Hot Tub 2.0

by Kathleen Jarschke-Schultze

Tales of off-grid living from seasoned homesteader Kathleen Jarschke-Schultze.

After years of wanting a hot tub, my husband Bob-O and I purchased a wood-fired model—the Snorkel. The tub assembly went very well. As did filling the tub with water and testing the stove. We had gathered a cord of dry, fallen wood. I made an insulating cover out of recycled bubble wrap. It was time to hone our skills at regulating the water temperature.

Temperature Trials

We had a floating thermometer in the tub. We hung a plastic canoe paddle by the tub for circulating the water. The Snorkel stove is made to run a hot, quick fire. The long-dead, very dry creek slash got a fire roaring in the stove, and then we tracked the water temperature. When the desired temperature is reached, the stove is manually closed down—both lid and damper. This quickly stops the heat from building further by cutting off the fire's oxygen supply.

While the hot tub instructions told us the 400 gallons of water would heat quickly, we were not prepared for a temperature rise of 64°F in four hours—kind of crazy. Midafternoon, the tub water was a scorching 114°F—way too hot to even dip a toe into. A temperature of 104°F is the hottest recommended for human comfort and safety in hot tubs or spas. But the temperature takeoff just happened. Well, it happened in part because of the distance between our house and the tub.

Tough Tubbing

Our tub is situated out the back door, across the driveway, and up a short rise to a semi-level area. It sits on the north side of the house, which means it gets the down-canyon winds that power our wind turbine, which is situated a little further out into the meadow. You gotta be tough to tub at our house, braving the chill winter winds and, at that time of year, treading through the snow.

Our hot-tub preparation ritual was this: We would trek out to the tub, check the fire in the stove, and add wood if the fire had died down. We would stir the tub with the canoe paddle, wait a minute or so, and then pull the floating thermometer to the side to read the temperature. It is an old liquid-in-glass type, so we had to be careful not to accidentally break it with the paddle. As the temperature neared the goal of 104°F, the trips to the tub multiplied. But after we had raised the temperature too high on several occasions, Bob-O decided to devise a system where we could do the stirring and the temperature check from the house.

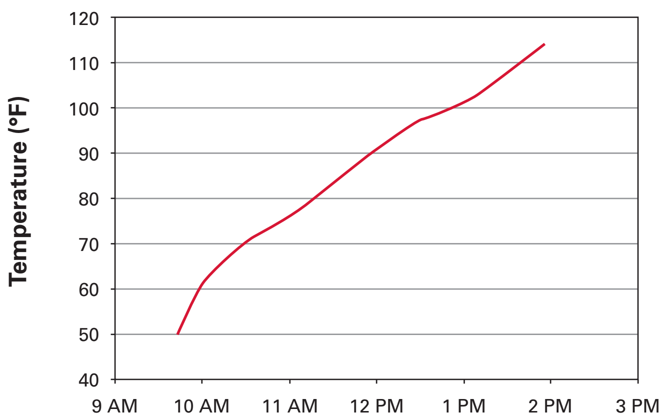
Tub 2.0

Since he had already buried a power line to the hot tub structure, he installed an all-weather covered outlet there. After much investigation and a couple of false leads, he bought an aquarium pump (8 watt, 620 gph) to circulate the water in the tub as it was heating. We start the pump when we kindle the fire in the stove. It works great. No more cold water lurking under the benches.

Bob-O found a wireless digital indoor/outdoor thermometer with a remote readout and a submersible temperature probe. He placed the probe about halfway down on the tub's inside wall. The remote readout sits on his desk.

Now, just by reading the remote display, we can tell exactly when the water reaches the right temperature for tubbing—or when we need to add wood. There is also a digital readout mounted by the tub so we can check the ambient and tub temperatures while we are in the water. It's quite a clever setup.

Floating Thermometer Readings



The bubble wrap insulating cover had a brief lifespan and quickly disintegrated. So we replaced it with Snorkel's closed-cell foam insulating cover, cutting it to size. By judicious use of the scissors, we were almost able to cut two full-sized layers, doubling the thickness to increase the R-value. Having a short, flat side next to the wooden fence that shields the tubbers from the stove gave us enough extra for this to work. The top of one curve is only missing a 3-inch-wide strip. The double thickness of foam is very insulating—and light enough to move on and off the tub quickly and easily.

Tub Tea

We tubbed just about every night this winter. Bob-O would call when he left a job and I would start the fire. On weekends, we'd go in a couple of times a day. If the sun came out, we would drain the tub, scrub it down, and refill it using the solar pump in the well. It was quite a cold winter and the warmth of the tub was glorious. Ever see pictures of Japanese snow monkeys basking their bones in the hot springs? That was us, just less furry and not picking nits off each other.

At first the tannins leaching out of the cedar staves gave the water a brownish tint. I asked my sister Mary about this effect, as she has owned a Snorkel tub longer than we have. "Don't worry," she joked, "just think of it as sunless tanning." But I never noticed any tanning effect, which would have been welcome in the dead of winter.

Winter Spring

Just about four weeks after we started using the tub, the weather turned cold. I mean, *really* cold for these parts—7°F; the next night, 6°F; the night after that, it warmed up to 8°F. No rain, no snow—just cold.

Our house's water system is charged by a spring that's piped underground to a gravity-fed, 1,000-gallon concrete tank buried in the hillside across the creek. From there, the water line is buried down the hill and under the road, coming out of the bank about 5 feet above the creek. The pipe crosses over the creek before it is again buried all the way to the house. The creek crossing is the weak link, although the pipe is insulated with foam, wrapped with electrical heat tape, and covered with a protective metal pipe. The extra need for electricity for the heat tape is not an issue, since its use coincides with our plentiful wintertime hydropower supply.

The night it was 7°F, the water line across the creek froze—even with the heat tape turned on. The next morning, we used the solar pump and the well to fill buckets of water for use in the kitchen and the bathroom. While we were still pumping from the well, we drained, cleaned, and refilled the tub. I thought this was pretty tolerable. At least we weren't breaking a hole in the creek ice to get water. (Been there, done that.)

The next night it dropped another degree, and the water line from the solar pump and the wellhead froze. The water we had then was all we would have until things thawed. The house system even froze, up the buried pipeline underground and in the pipes under the house. The next night remained in the single digits. We had to conserve the water we had and wait for warmer weather, but we could still soak in the hot tub every night. It was a real comfort to be warm all over. Well, except our ears. We took to wearing hats in the tub.

Although the nights did not get above freezing for two more weeks, we were able to thaw the wellhead and pump line. We dipped water from the creek, heated it, and slowly poured it on the frozen areas. Once we had the well water pumping again, I used bags of old packing peanuts to cover the exposed areas, then weighted the bags down. On sunny days, we were able to drain, clean, and fill the Snorkel. (Doing that about once a week was just right.) We topped off the buckets in the house at the same time.

There have been a few times through the years when our spring-fed holding tank was drained. Usually on those occasions, we would hook up a hose between the well line and an outside faucet on the house to the holding tank, using the solar pump to back-charge the house's holding tank. With all the frozen lines in the house system, though, we just had to wait for a thaw. When the system did thaw, we found that the spring itself had frozen—the first time that has happened in the 20 years we've been here—but then we were able to use the well to back-charge the tank.

Warm Regards

Hot water is a miracle. Just wait till you don't have it. Was it serendipity that we got the hot tub just in time to be such a comfort in our time of need? Clean living? Kismet? We were just glad we had the Snorkel. We are tubbing regularly and look forward to many years of heated relaxation and quiet conversation under the stars or surrounded by snow. You know, moonlight on the snow really is wonderful.

Access

Kathleen Jarschke-Schultze (kathleen.jarschke-schultze@homepower.com) has leaped into the blogosphere at www.theoffgridlife.com from her off-grid home in northernmost California.

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Arcata, CA. Workshops & presentations on RE & sustainable living. Info: Campus Center for Appropriate Technology • 707-826-3551 • ccat@humboldt.edu • www.humboldt.edu/~ccat

Hopland, CA. Workshops on PV, wind, hydro, alternative fuels, green building & more. Solar Living Institute • 707-744-2017 • sli@solarliving.org • www.solarliving.org

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Iowa City, IA. Iowa RE Assoc. meetings. Info: 319-341-4372 • irenew@irenew.org • www.irenew.org

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Hudson, MA. Workshops: PV, wind & solar thermal. Intro to advanced. Info: AltE Univ. • http://workshops.altenergystore.com

MICHIGAN

West Branch, MI. Intro to solar, wind & hydro. First Friday each month. Residential system design & layout. Info: 989-685-3527 • gotter@m33access.com • www.loghavenbbb.com

MISSOURI

Gerald, MO. Workshops on energy efficiency, PV, wind, solar heating & more. Info: Evergreen Institute • info@evergreeninstitute.org • www.evergreeninstitute.org

Hartsburg, MO. Workshops & online courses on PV & more. Info: Show Me Solar • www.showmesolar.org

New Bloomfield, MO. Workshops, monthly energy fairs & other events. Info: MO RE • 800-228-5284 • info@moreenergy.org • www.moreenergy.org

MONTANA

Whitehall, MT. Seminars, workshops & tours. Straw bale, cordwood, PV & more. Info: Sage Mt. Center • 406-494-9875 • www.sagemountain.org

NEW MEXICO

Six NMSEA regional chapters meet monthly, with speakers. Info: NM Solar Energy Assoc. • 505-246-0400 • info@nmsea.org • www.nmsea.org

NEW YORK

Jun. 14–18, ’10 (again Jul. 5–9 & Aug. 2–6). Delhi, New York. PV Design & Installation Basics training. Info: SUNY • 607-746-4545 • communityservices@delhi.edu

Oct. 18–21, ’10. Chatham, NY. PV Design & Installation Basics. Site analysis, system sizing & some hands-on. Info: SunDog Solar • betsy@sundogsolar.net • www.sundogsolar.net

OHIO

Cleveland, Cincinnati, etc. Workshops & RE events throughout the state. Info: www.greenenergyohio.org

OREGON

Jul. ’10 EORenew workshops. John Day, OR. Jul. 19–22: Cob Bench Sculpture & Construction; Jul. 22: Domestic SHW; Jul. 23: Cob Techniques & Materials Lab; Jul. 26–27: Earthen Plasters. Info: (see EORenew below)

Jul. 23–25, ’10. John Day, OR. SolWest RE Fair. Exhibits, workshops, speakers. Info: EORenew • 541-575-3633 • info@solwest.org • www.solwest.org

Cottage Grove, OR. Adv. Studies in Appropriate Tech. internships. Info: Aprovecho Research Center • 541-942-8198 • apro@efn.org • www.aprovecho.net

PENNSYLVANIA

Jun. 26–27, ’10. Dallas, PA. NE PA Energy Solutions Expo. Exhibitors & vendors: technology, products & innovations to conserve, reduce, or supplement energy use. Info: www.pnercd.org

TENNESSEE

Summertown, TN. Workshops on PV, alternative fuels, green building & more. Info: The Farm • 931-964-4474 • ecovillage@thefarm.org • www.thefarm.org

TEXAS

Austin, El Paso, Houston, North TX & San Antonio. TX Solar Energy Society chapters and affiliates have regular meetings across the state: Info: www.txses.org

WASHINGTON STATE

Oct. 9, ’10. Guemes Island, WA. Intro to RE. Info: see SEI listing in CO.

Oct. 11–16, ’10, Guemes Island, WA. PV Fundamentals & Grid-Tied Design. Info: see SEI listing in CO.

Oct. 18–23, ’10. Guemes Island, WA. Wind-Electric Systems Maintenance & Repair. Info: (see SEI listing in CO)

Oct. 25–30, ’10. Guemes Island, WA. Homebuilt Wind Generators. Info: see SEI listing in CO.

WISCONSIN

Jun. 15–16, ’10. Stevens Point, WI. Small Wind Conference, for installers and industry. Info: www.smallwindconference.com

Jun. 18–20, ’10. Custer, WI. The Energy Fair (a.k.a. MREF). Exhibits & workshops on solar, wind, green building, transportation, energy efficiency & more. Home tours, silent auction, Kids’ Korral, entertainment, speakers. Info: See MREA listing below.

Custer, WI. MREA ’10 workshops: Basic, int. & adv. PV, SHW & space heating, wind; site assessor certification, RE business, straw bale, cordwood, masonry heaters & more. Info: MREA • 715-592-6595 • info@the-mrea.org • www.the-mrea.org

Amherst, WI. Artha ’10 workshops: Intro to Solar Water & Space Heating Systems; Installing a Solar Water Heating System; Living Sustainably & more. Info: Artha • 715-824-3463 • chamomile@arthaonline.com • www.arthaonline.com

INTERNATIONAL

CANADA

Jul. 2–9, ’10. Smithers, BC. Off-grid Systems for Remote Locations. Info: www.buckvilleenergy.com

Downsview, ON. Workshops on RE, PV, wind, SHW, green building, efficient heating & more. Info: www.kortright.org

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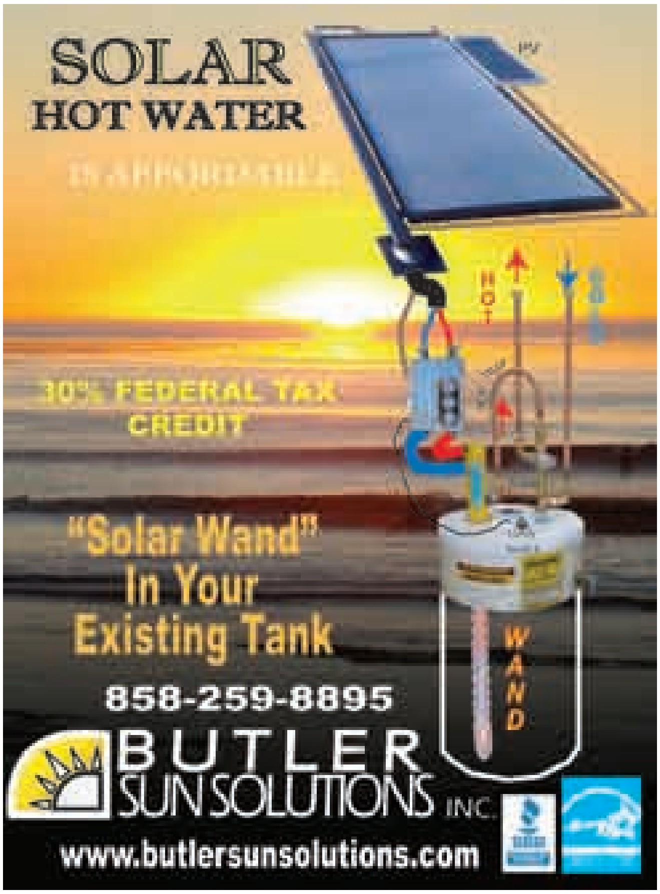
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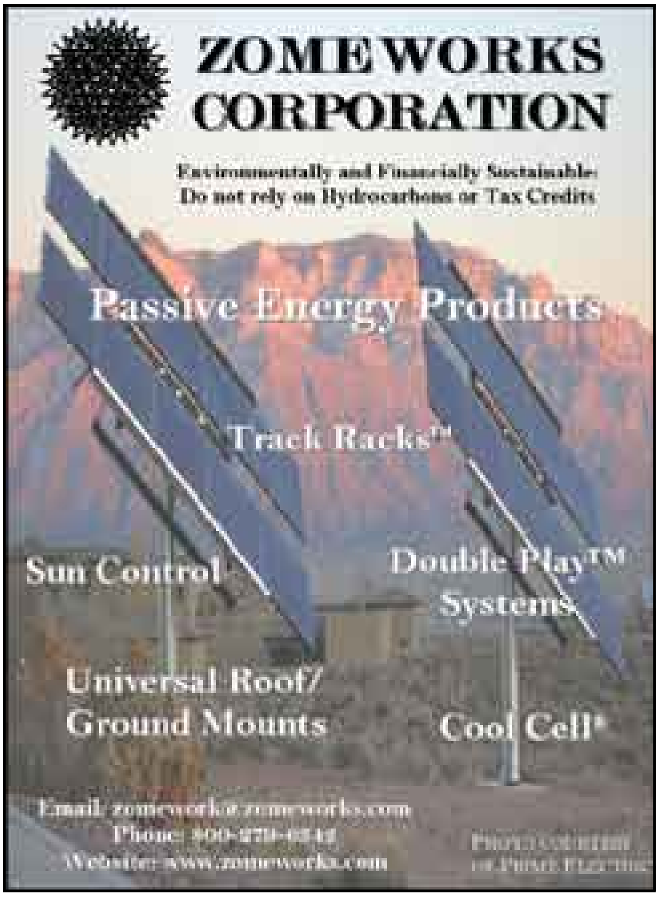
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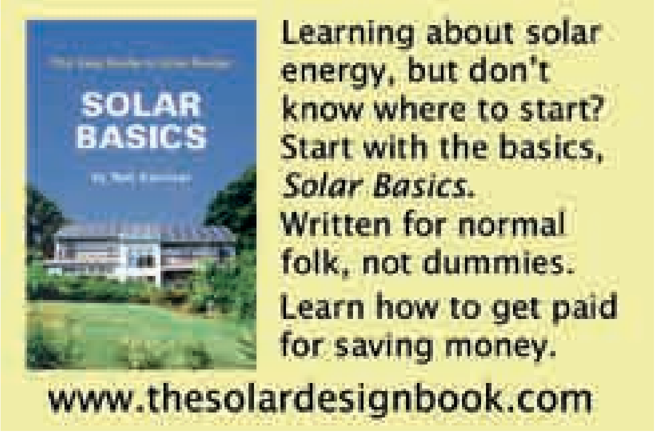
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What is the *NEC*?

The *National Electrical Code (NEC)* is a standard of minimum requirements necessary to achieve safe electrical installations. Sponsored by the National Fire Protection Association (NFPA), its purpose is "the practical safeguarding of persons and property from the hazards arising from the use of electricity."

The first version of the *Code*, developed in 1897 by members of the insurance, fire, electrical, and sprinkler industries, reconciled a variety of standards in use to one standard. The NFPA Committee on the *NEC* maintains and updates the *Code* every three years. Several code-making panels meet to discuss and revise the finer points and intent of the *NEC*, taking recommended changes to the NFPA committee. The most recent edition is the *2008 NEC*. The *2011 NEC* will be available at the end of this year. PV standards first appeared in the *NEC* 1984 edition and have evolved as equipment and applications have grown. Small wind is slated to become part of the 2011 edition.

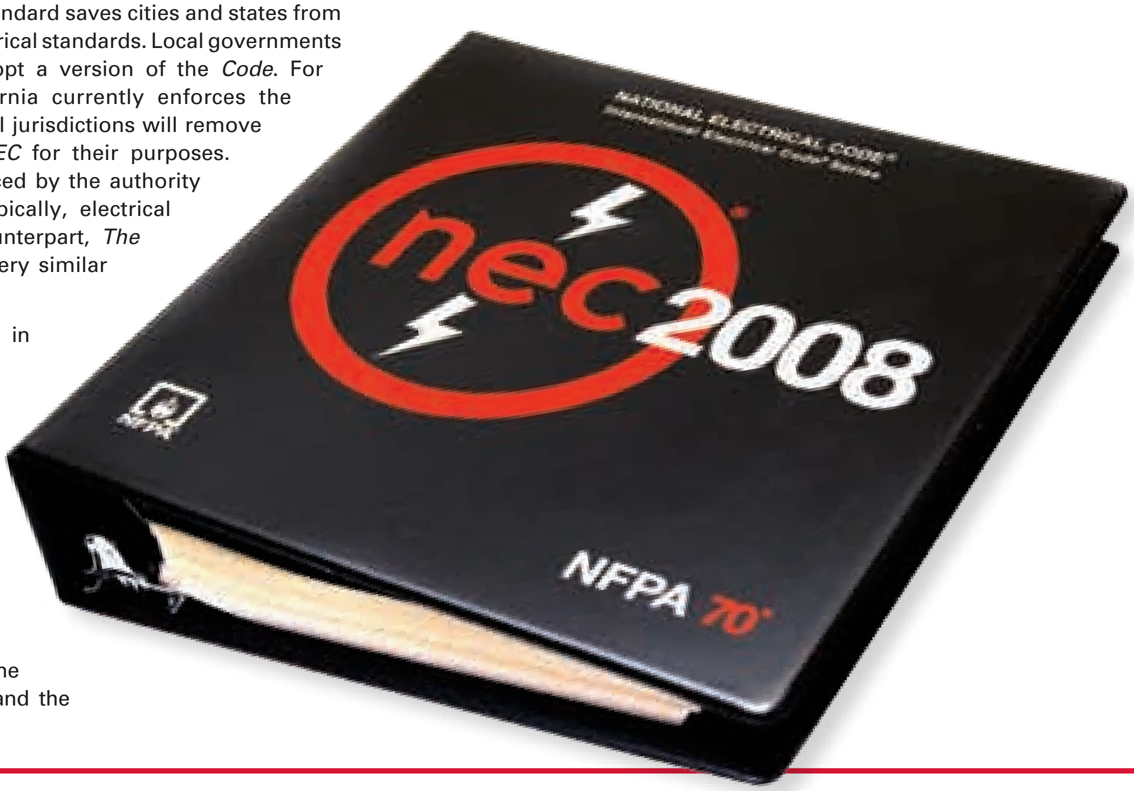
Although not law, the *NEC* is often adopted by local authorities to enforce. Using a national standard saves cities and states from having to create their own electrical standards. Local governments may take a few years to adopt a version of the *Code*. For example, the state of California currently enforces the *2005 NEC*. In some cases, local jurisdictions will remove or amend portions of the *NEC* for their purposes. Electrical standards are enforced by the authority having jurisdiction (AHJ)—typically, electrical inspectors. The Canadian counterpart, *The Canadian Electrical Code*, is very similar to the *NEC*.

The *Code* encompasses wiring in buildings, mobile homes, and on properties, but does not address boats or equipment controlled by electric or communications utilities in their distribution network. In designing residential kitchens, commercial production facilities, or standby generator systems, for example, there are hundreds of sections of the *Code* that come into play in the initial design and the actual execution of the work.

The general chapters cover all electrical installations by defining things like wire types, conduit, proper grounding, and proper wire and enclosure sizing. As an example, any particular wire does not care if it is used for a hot tub or a motor; it has a limited capacity of delivering current before overheating, and sizing is spelled out in the *Code* based on current and temperature factors. Photovoltaic systems have a section in the *Code's* "Special Equipment" chapter under Article 690, which supplements the standard outlined in many other chapters/articles.

As with most standards, the *NEC* is quite technical and not written for leisurely reading. If you are looking for electrical advice, it's not an easy place to find answers. Using the *NEC* properly takes expertise and experience, and even seasoned professionals sustain heated debates about interpretation of the *Code*. Typically, conversations involve deciding which part of the *Code* pertains to the situations at hand and choosing a path that achieves the desired result—safeguarding people and properties that use electricity.

—Erika Weliczko



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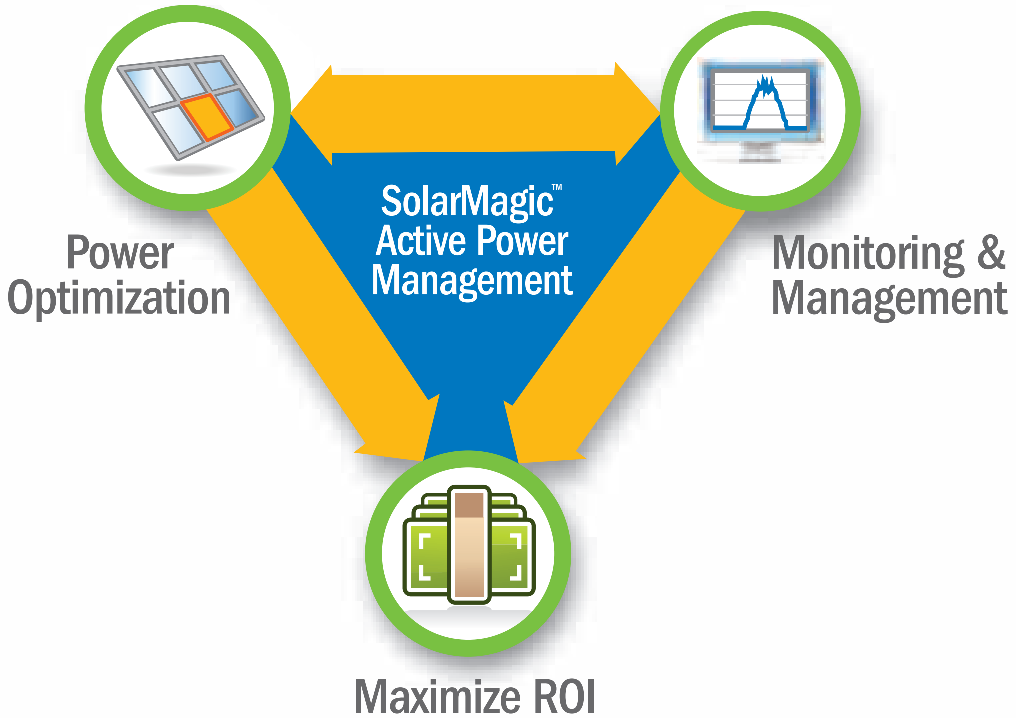

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*Based on an independent study conducted by Photon International, September 2009.